

SimEvents[®]
User's Guide



MATLAB[®]&SIMULINK[®]

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SimEvents[®] *User's Guide*

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Working with Entities

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Entity Types

An entity type is the identification tag associated with any block that creates entities in your model. For the **Entity Generator** block, you assign a name to the entity type on the **Entity type** tab of the generation block. From this block, each new entity receives this tag. For example, the name of the entity type associated with an **Entity Generator** in your model might be **Customer**. Each entity that originates in that block receives this entity type. A **Composite Entity Creator** block also generates new entities by combining two or more existing entities to form a new composite entity. You can assign a new entity type name to the entity type (named **Combined** by default).

Note: The **Entity Replicator** block also generates new entities by outputting copies of an incoming entity. However, because the incoming entity already possesses an entity type, the block does not create new entity types for the copies.

As an entity progresses through your model, its type does not change. Even if the entity acquires attribute, timeout, or timer data that give it a more complex structure, the entity type remains the same. Although a **Composite Entity Creator** block forms new composite entities with a new entity type, the underlying entity types remain the same.

By default, each new entity type that SimEvents[®] creates in your model uses the name **Entity**.

The **Entity Generator** block can generate these entity types:

- **Anonymous** — Unstructured entity with no name. You can specify only entity priority and initial data value for anonymous entity types.
- **Structured** — Structured entity type that you define in this block dialog box. You can name entities, specify priorities, and specify attributes for the entity in the **Define attributes** section of the **Entity Generator** block. Attributes are data carried by entities. Creating a structured entity in this tab is a convenient way to create an entity without having to create an associated bus object in Simulink[®].
- **Bus object** — Entity type that you define using Simulink bus objects. You can name entities, specify priorities, and specify attributes for the entity. To specify this entity type, you must have an existing bus object, created in Simulink, and use that bus object name as the name of the entity type. This bus object:

- Must be a valid bus object with one or more bus elements at a single level.
- Cannot contain nested buses.
- Cannot contain variable-size elements. This limitation is also true for entities registered as bus objects through the Composite Entity Creator block.

See Also

Composite Entity Creator | Composite Entity Splitter | Discrete Event Chart | Entity Gate | Entity Generator | Entity Input Switch | Entity Multicast | Entity Output Switch | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System | Multicast Receive Queue | Resource Acquirer | Resource Pool | Resource Releaser

Related Examples

- “Generate Entities When Events Occur” on page 1-7
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More About

- “What Is an Entity?”
- “Role of Entity Ports and Paths”
- “Attribute Value Support” on page 1-35
- “Bus Objects”

Events and Event Actions

In a discrete-event simulation, an event is an observation of an instantaneous incident that may change a state variable, an output, and/or the occurrence of other events. You can create event actions to occur when entities change state, for example, when an entity exits a block. For a list of blocks and the actions they can have, see “Storage Actions”.

An event calendar tracks upcoming events for a model during a discrete-event simulation. For more information on the event calendar, see “Event Calendar” on page 6-2

Create Event Actions

Define event actions on the **Event actions** tab of a block. These are the possible actions for which you can create events.

Entity Generator	Entity Queue	Entity Server	Entity Terminator	Resource Acquirer
Entity generation	Entity entry to queue block	Entity entry to server block	Entity entry to terminator block	Entity entry to acquirer block
Entity exit from block	Entity exit from block	Service completion of entity	N/A	Entity exit from acquirer block
N/A	Entity is blocked	Entity exit from block	N/A	N/A
N/A	N/A	Entity is blocked	N/A	N/A
N/A	N/A	Entity is preempted	N/A	N/A

In event actions, you can also modify entity attributes (*entityName.attributeName*), entity priorities (`sys.entity.priority`), and entity IDs (`sys.entity.id`).

The `seExampleTankFilling` example has two event actions defined, in the Entity Generator and Entity Server blocks. This example recreates the event action in the Entity Server block.

- 1 In a new model, from the SimEvents library, drag the Entity Server and Simulink Function blocks.

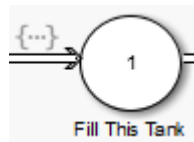
2 In the Entity Server block:

- Click the **Entity actions** tab.
- To create an action on entity entry, click **Entry**.
- In the **Entry action** section, type:

```
startFilling(entity.Capacity);
```

This command calls the function, `startFilling`.

The ingoing line to the Entity Server block icon updates with the event action icon (`{...}`) indicating that the block defines an event action.



3 In the Simulink Function block:

- a In Trigger Port, enter `startFilling` in the **Function name** parameter.
- b Drag in an Inport block and rename it to `cap`.
- c Rename the `u` input to `capacity` and connect it to `cap`.
- d Remove the `y` output.
- e Drag in a MATLAB Function block and an Outport block.
- f In the MATLAB Function, enter the code:

```
function y = toggle()
%#codegen
persistent u

if isempty(u)
    u = -1;
end

if u == -1
    u = 1;
else
    u = -1;
end
```

`y = u;`

- g** Connect the `y` output of the MATLAB Function block to the Outport block and rename the Outport block to `reset`.

You have now defined the `startFilling` function for the event action. To optionally visualize the connection between the Entity Server block and the Simulink Function block, in the Editor, select **Display > Function Connectors**.

See Also

Composite Entity Creator | Composite Entity Splitter | Discrete Event Chart | Entity Gate | Entity Generator | Entity Input Switch | Entity Multicast | Entity Output Switch | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System | Multicast Receive Queue | Resource Acquirer | Resource Pool | Resource Releaser

Related Examples

- “Generate Entities When Events Occur” on page 1-7

More About

- “What Is an Event?”
- “What Is an Entity?”
- “Run Computations on Events” on page 1-10
- “Event Calendar” on page 6-2

Generate Entities When Events Occur

In this section...

“Generate Entity When First Entity is Destroyed” on page 1-7

“Generate Event-Based Entities Using Data Sets” on page 1-9

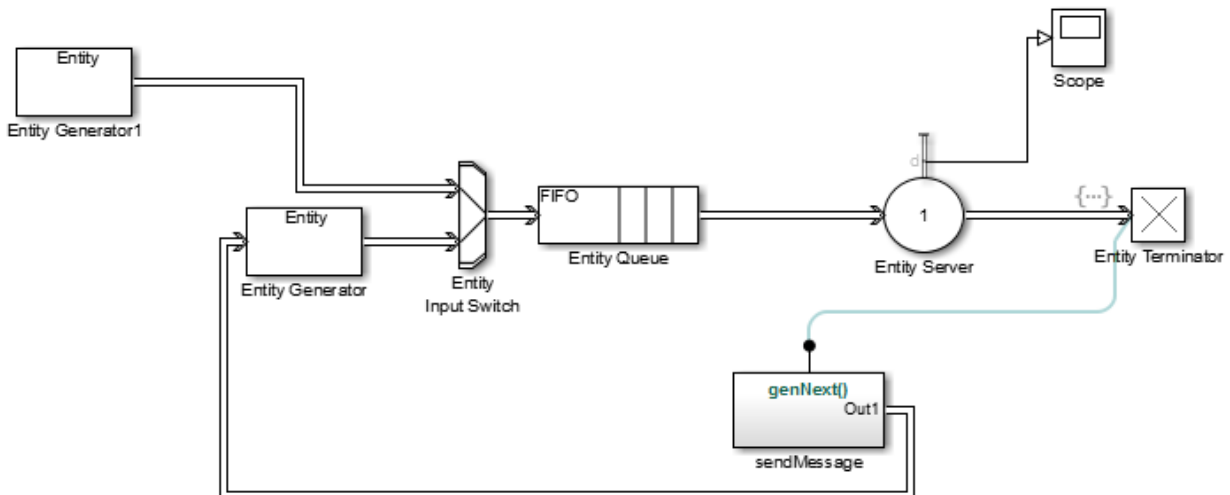
In addition to time-based entity generation, the **Entity Generator** block enables you to generate entities in response to events that occur during the simulation. In event-based generation, a new entity is generated whenever a message arrives at the input port of the **Entity Generator** block.

Event times and the time intervals between pairs of successive entities are not necessarily predictable in advance.

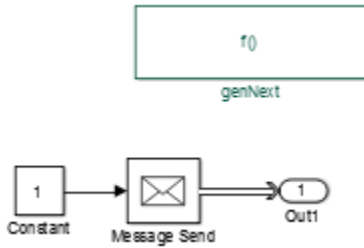
Generating entities when events occur is appropriate if you want the dynamics of your model to determine when to generate entities.

Generate Entity When First Entity is Destroyed

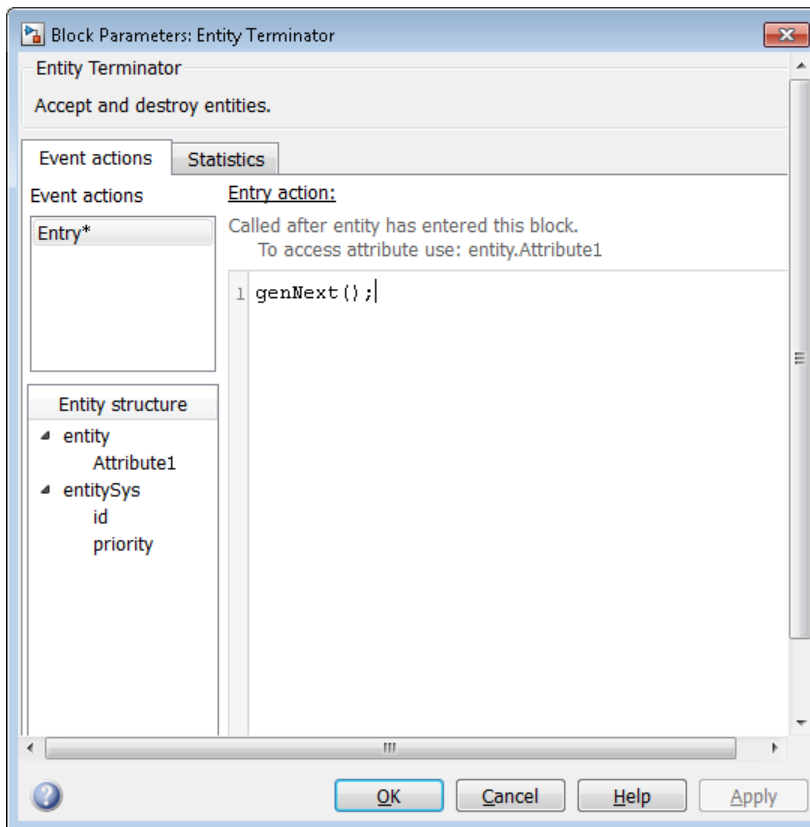
To generate an entity when the first entity is destroyed, use two **Entity Generator** blocks and a **Simulink Function** block. The **Entity Terminator** block calls the **Simulink Function** after destroying the first entity.



In this example, Entity Generator1 generates the first entity. SendMessage contains the genNext function, which sends a message.



The Entity Terminator block calls the genNext function.



Generate Event-Based Entities Using Data Sets

For an example of an example that uses an Excel[®] spreadsheet, see [Generating and Initiating Entities](#).

See Also

[Composite Entity Creator](#) | [Composite Entity Splitter](#) | [Discrete Event Chart](#) | [Entity Gate](#) | [Entity Generator](#) | [Entity Input Switch](#) | [Entity Multicast](#) | [Entity Output Switch](#) | [Entity Queue](#) | [Entity Replicator](#) | [Entity Server](#) | [Entity Terminator](#) | [MATLAB Discrete Event System](#) | [Multicast Receive Queue](#) | [Resource Acquirer](#) | [Resource Pool](#) | [Resource Releaser](#)

Related Examples

- [“Specify Intergeneration Times for Entities”](#) on page 1-11
- [“Manipulate Entity Attributes”](#) on page 1-26
- [“Inspect Structures of Entities”](#) on page 1-30
- [“Generate Multiple Entities at Time Zero”](#) on page 1-17
- [“Count Simultaneous Departures from a Server”](#) on page 1-20
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More About

- [“What Is an Entity?”](#)
- [“Role of Entity Ports and Paths”](#)
- [“Attribute Value Support”](#) on page 1-35

Run Computations on Events

You can run computations on events using event actions by:

- Writing event actions using MATLAB[®] code that perform computations.
- Using the Simulink Function block to call a function that performs computations.

With either of these methods, you can use attribute-defined data to perform the computations.

More About

- “What Is an Event?”
- “Event Calendar” on page 6-2

Specify Intergeneration Times for Entities

The intergeneration time is the time interval between successive entities that the block generates. You can have a generation process that is:

- Periodic
- Sampled from a random distribution or time-based signal
- From custom code

For example, if the block generates entities at $T = 50$, $T = 53$, $T = 60$, and $T = 60.1$, the corresponding intergeneration times are 3, 7, and 0.1. After each new entity departs, the block determines the intergeneration time that represents the interval until the block generates the next entity.

Determine Intergeneration Time

You configure the **Entity Generator** block by indicating criteria that it uses to determine intergeneration times for the entities it creates. You can generate entities:

- From random distribution
- Periodically
- At arbitrary times

Use the dropdown list in the **Time source** parameter of the **Entity Generation** block to determine intergeneration times:

- **Dialog**

Uses the **Period** parameter to periodically vary the intergeneration times.

- **Signal port**

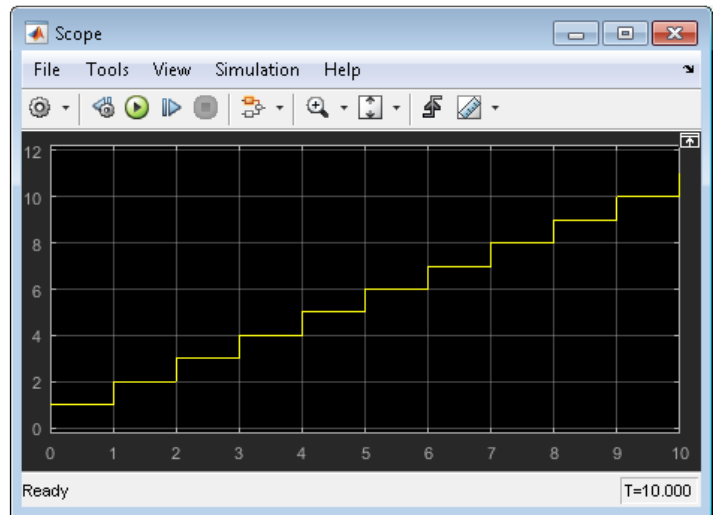
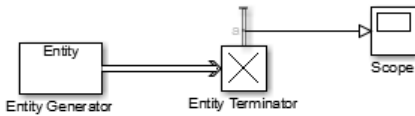
Uses a signal from an external block, such as the **Sine wave** block, to vary the intergeneration times.

- **MATLAB action**

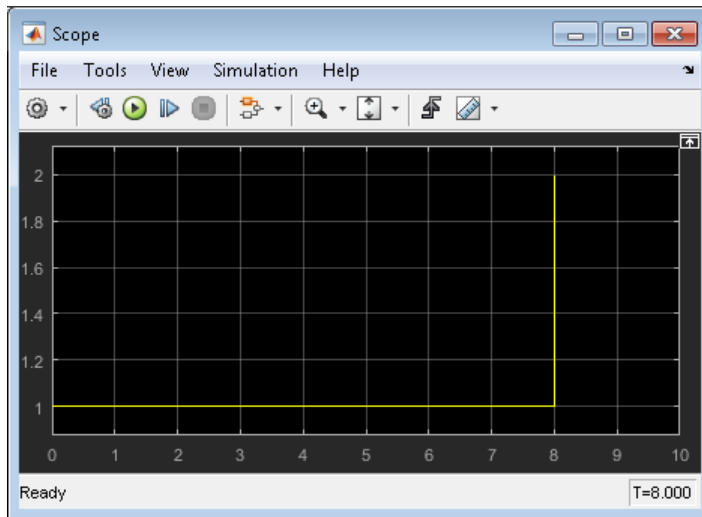
Enables an **Intergeneration time action** field, in which you enter MATLAB code to customize the intergeneration times.

Periodically Vary the Intergeneration Times

- 1 In a new model, from the SimEvents library, drag the Entity Generator, Entity Terminator, and Scope blocks.
- 2 In the **Entity Generation** tab of the Entity Generator, set the **Time source** parameter to **Dialog**.
- 3 In the **Statistics** tab of the Entity Terminator block, select the **Number of entities arrived** check box.
- 4 Connect these blocks and simulate the model. The period is 1.



- 5 Vary the period to 8 and simulate the model again. Observe the change in the scope.

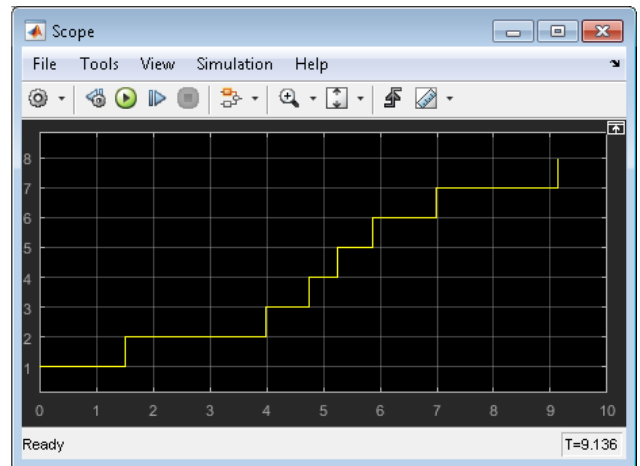
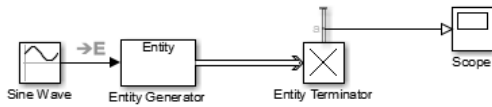


Use a Signal to Vary the Intergeneration Times

- 1 In a new model, from the SimEvents library, drag the Entity Generator, Entity Terminator, Sine Wave, and Scope blocks.
- 2 In the **Entity Generation** tab of the Entity Generator, set the **Time source** parameter to **Signal** port.

A new signal port appears on the Entity Generator block.

- 3 In the **Statistics** tab of the Entity Terminator block, select the **Number of entities arrived** check box.
- 4 Double-click the Sine Wave block. By default, the first value of the Sine Wave block is 0. To add a constant value to the sine to produce the output of this block, change the **Bias** parameter to another value, for example, 1.5.
- 5 Connect these blocks and simulate the model.



Upon generating each entity, the **Entity Generator** block reads the value of the input signal and uses that value as the time interval until the next entity generation.

Notice the capital **E** on the signal line from the **Sine Wave** block to the **Entity Generator** block. This icon indicates the transition from a time-based system to a discrete-event system.

Customize the Variation of the Intergeneration Times

- 1 In a new model, from the SimEvents library, drag the **Entity Generator**, **Entity Terminator**, and **Scope** blocks.
- 2 In the **Entity Generation** tab of the **Entity Generator**, set the **Time source** parameter to **MATLAB action**.

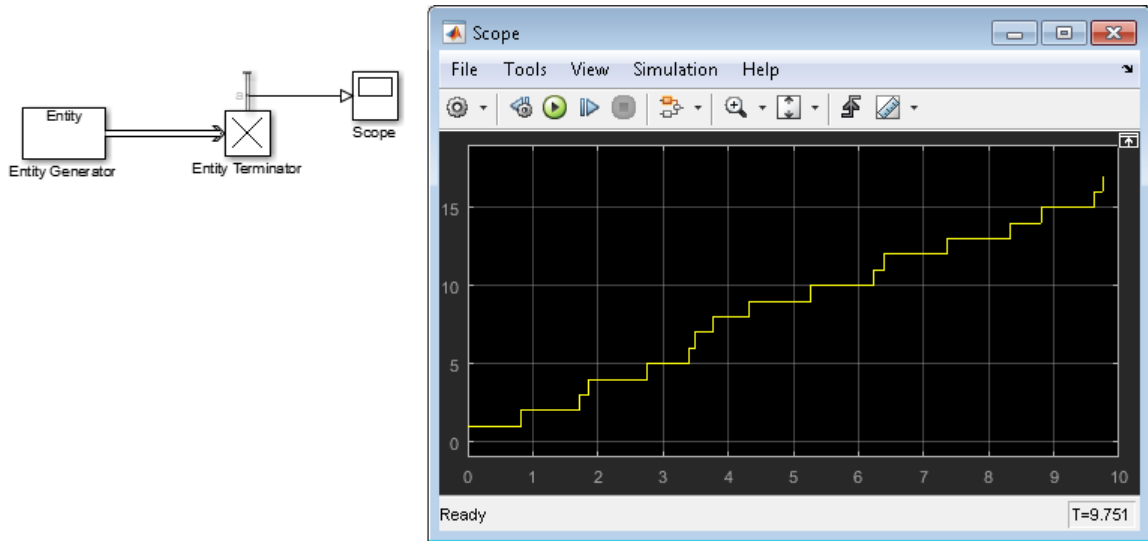
A new **Intergeneration time action** field appears on the **Entity Generator** block.

- 3 To customize the intergeneration times for your model, in the **Intergeneration time action** field, enter MATLAB code, for example:

```
dt = rand();
```


Note: For intergeneration times, you must set the fixed name, *dt*. You cannot set any other variable name for this value.

- 4 In the Statistics tab of the Entity Terminator block, select the **Number of entities arrived** check box.
- 5 Connect these blocks and simulate the model.



See Also

Discrete Event Chart | Entity Server | Entity Generator | Entity Queue | Entity Replicator | Entity Terminator | MATLAB Discrete Event System

Related Examples

- “Generate Entities When Events Occur” on page 1-7
- “Manipulate Entity Attributes” on page 1-26
- “Inspect Structures of Entities” on page 1-30
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More About

- “What Is an Entity?”
- “Role of Entity Ports and Paths”
- “Attribute Value Support” on page 1-35

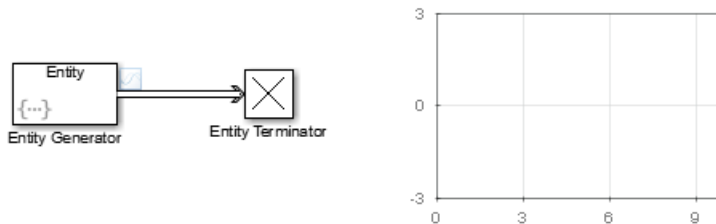
Generate Multiple Entities at Time Zero

Suppose that you want to:

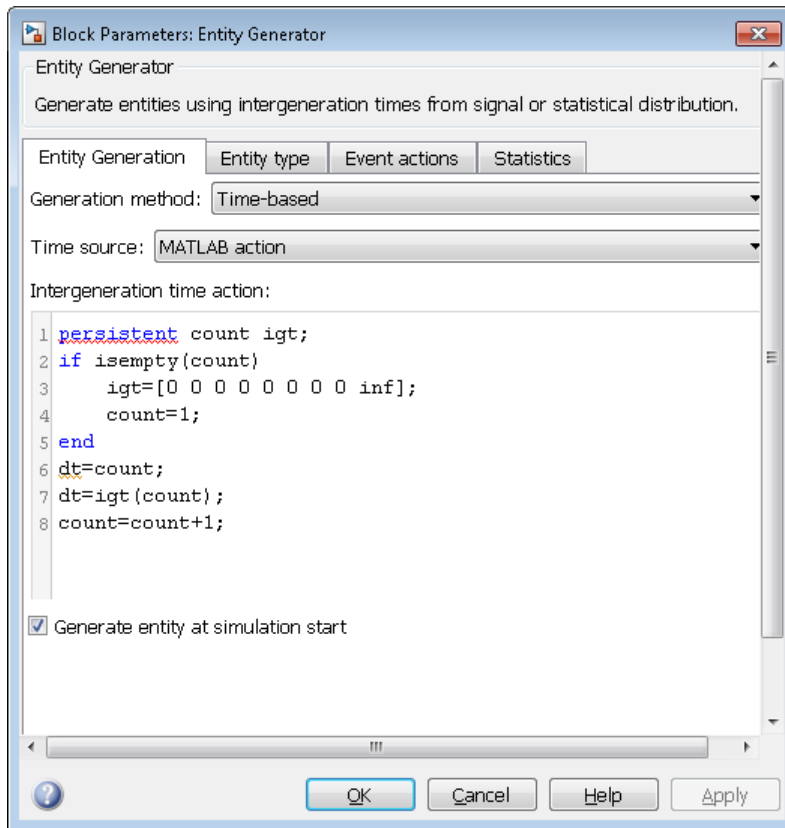
- Preload a queue or server with entities at the start of the simulation, before you analyze queuing or processing delays.
- Initialize the capacity of a shared resource before you analyze resource allocation behavior.

In these scenarios, you can simultaneously generate multiple entities at the start of the simulation. You can then observe the behavior of only those entities for the remainder of the simulation.

To generate multiple entities at time 0, use MATLAB code in the Entity Generator block.



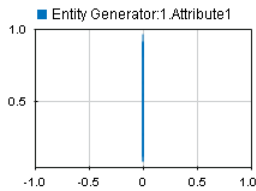
- 1 In a new model, from the SimEvents library, drag the Entity Generator, Entity Terminator, and Dashboard Scope blocks.
- 2 Double-click the Entity Generator block.
- 3 From the **Time source** drop-down list, select **MATLAB action**.
- 4 In the **Intergeneration time action** field, use MATLAB code to enter the number of entities that you want to generate. For example, you could use 8. In that case, at simulation time **0**, the Entity Generator block generates 8 simultaneous events.



- 5 In the **Events action** tab, randomize the entity attribute. Select the **Generate** event action and, in the **Generate action** field, enter the MATLAB code:

```
entity.Attribute1=rand();
```

The output of the Dashboard Scope block shows that the software generates multiple entities at time **0**.



See Also

Composite Entity Creator | Composite Entity Splitter | Discrete Event Chart | Entity Gate | Entity Generator | Entity Input Switch | Entity Multicast | Entity Output Switch | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System | Multicast Receive Queue | Resource Acquirer | Resource Pool | Resource Releaser

Related Examples

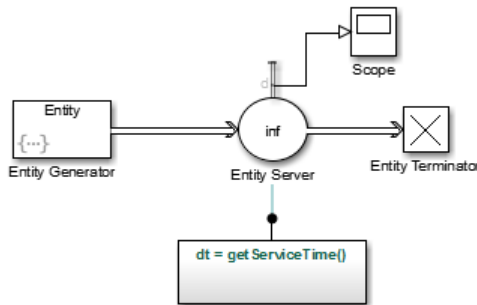
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More About

- “What Is an Entity?”
- “Role of Entity Ports and Paths”
- “Attribute Value Support” on page 1-35

Count Simultaneous Departures from a Server

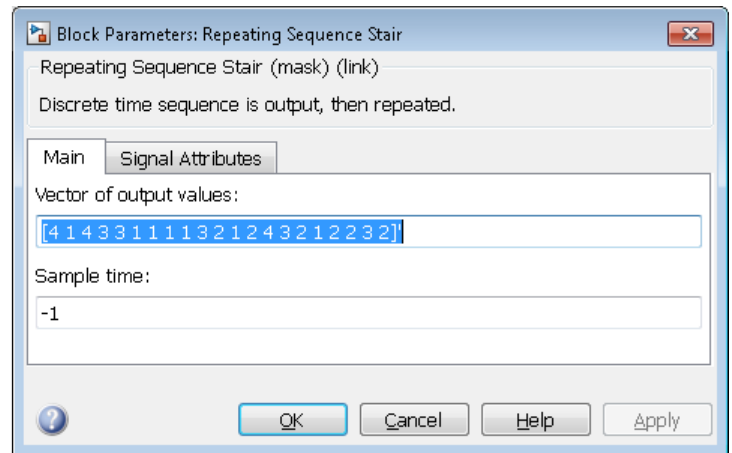
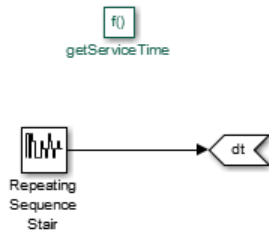
This example shows how to count the simultaneous departures of entities from a server. Use the **d** output from the **Entity Server** block to learn how many entities have departed (or arrived at) the block. The output signal also indicates when departures occurred. This method of counting is cumulative throughout the simulation.



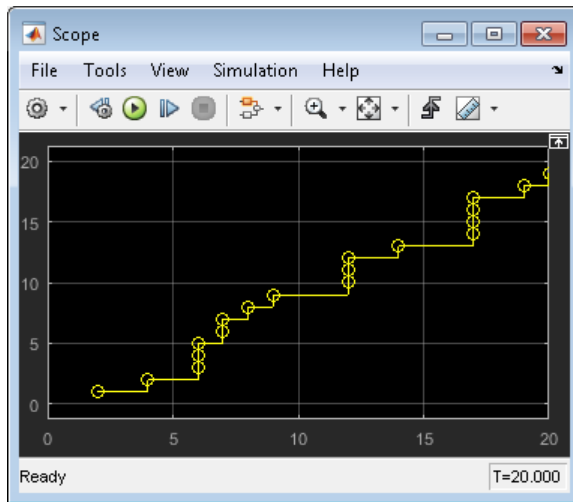
- 1 In a new model, from the SimEvents library, drag the Entity Generator, Entity Server, Entity Terminator, Simulink Function, and Scope blocks.
- 2 Double-click the Entity Generator block.
 - In the **Event actions** tab, to generate random attribute values, enter:


```
entity.Attribute1=rand();
```
- 3 Double-click the Entity Server block. In the **Main** tab:
 - In the **Capacity** parameter, enter `inf`.
 - For the **Service time** parameter, select **MATLAB** action.
 - In the **Service time action** parameter, enter:


```
dt = getServiceTime();
```
 - In the **Statistics** tab, select **Number of entities departed, d**.
- 4 In the Simulink Function block, define the `getServiceTime` function.



- 5 Connect the blocks as shown and simulate the model.



See Also

Composite Entity Creator | Composite Entity Splitter | Discrete Event Chart | Entity Gate | Entity Generator | Entity Input Switch | Entity Multicast | Entity Output Switch | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System |

Multicast Receive Queue | Resource Acquirer | Resource Pool | Resource Releaser

Related Examples

- “Generate Entities When Events Occur” on page 1-7
- “Specify Intergeneration Times for Entities” on page 1-11
- “Manipulate Entity Attributes” on page 1-26
- “Inspect Structures of Entities” on page 1-30
- “Generate Multiple Entities at Time Zero” on page 1-17
- “Combine Entities” on page 1-33
- “Replicate Entities on Multiple Paths” on page 1-34

More About

- “What Is an Entity?”
- “Role of Entity Ports and Paths”
- “Attribute Value Support” on page 1-35

Working with Entity Attributes

In this section...

“Attach Attributes” on page 1-23

“Set Attributes” on page 1-23

You can attach data to an entity using one or more *attributes* of the entity. Each attribute has a name and a numeric value. You can read or change the values of attributes during the simulation.

For example, suppose your entities represent a message that you are transmitting across a communication network. You can attach the length of each particular message to the message itself using an attribute named `length`.

You can also use attributes to specify the amount of a resource for your model. For more information, see “Model with Resources” on page 4-2.

Attach Attributes

To attach attributes to an entity, use the **Entity Generator** block. Attribute attachments can create new attributes or change the values of existing attributes. You can attach attributes such as:

- Constant value
- Random numbers
- Elements of either a vector in the MATLAB workspace or a vector that you can type in a block dialog box
- Values of an output argument of a MATLAB function that you write
- Values of a signal
- Outputs of a function defined in Simulink or Stateflow[®] environment that you write.



Set Attributes

To build and manage the list of attributes to attach to each departing entity, use the controls under the **Define attributes** section of the **Entity Generator** block. Each attribute appears as a row in a table.

Using these controls, you can:

- Add an attribute manually to attach to the entity.
- Modify an attribute that you added to the table from the **Available Attributes** list to attach to the entity.

The buttons under **Set Attribute** perform these actions.

Button	Action	Notes
	Add a template attribute to the table.	Rename the attribute and specify its properties.
	Remove the selected attribute from the attribute table.	When you delete an attribute this way, no confirmation appears and you cannot undo the operation.

The table displays the attributes you added manually. Use it to set these attribute properties.

Property	Specify	Use
Attribute Name	The name of the attribute. Each attribute must have a unique name.	Double-click the existing name, and then type the new name.
Attribute Initial Value	The value to assign to the attribute (when the attribute comes from the dialog box).	Double-click the value, and then type the value you want to assign.

See Also

Discrete Event Chart | Entity Generator | MATLAB Discrete Event System

Related Examples

- “Manipulate Entity Attributes” on page 1-26

More About

- “What Is an Entity?”

- “Attribute Value Support” on page 1-35
- “Combine Entities” on page 1-33

Manipulate Entity Attributes

The attributes table describes some ways that you can use data that you have attached to an entity.

- Create a signal
- Create a plot
- Compute a different attribute value
- Help specify behavior of a block that supports the use of attribute values for block parameters. Examples are the service time for a server and the selected port for an output switch.

Suppose that your entity possesses an attribute with one of these quantities:

- Service time to be used by a downstream server block
- Switching criterion to be used by a downstream switch block

When an entity with one of these attribute quantities arrives at a server or switch block, you can directly reference the attribute using an option on the server or switch block dialog box. This approach is better than creating a message or signal with the value and delivering it before the entity arrives.

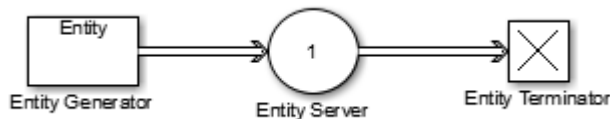
Write Functions to Manipulate Attributes

To manipulate attributes using code, use the **Event actions** tab of a block. In this tab, you can write MATLAB code to manipulate the attribute. To access the attribute, use the notation *entityName.attributeName*. For example:

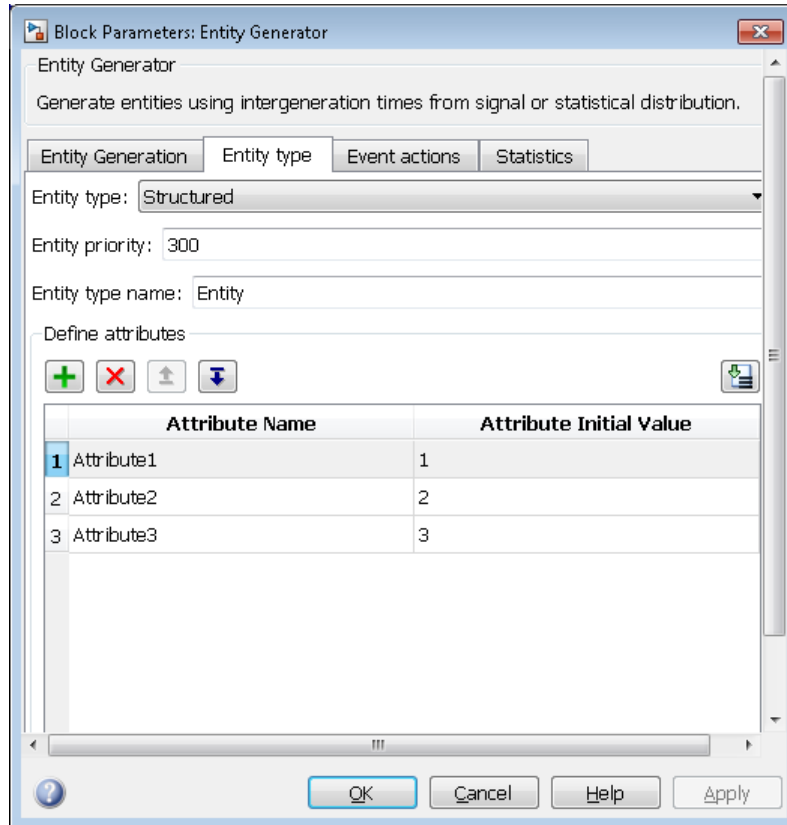
```
entity.Attribute1=5;
```

For example, you might want manipulate the attributes for service completion.

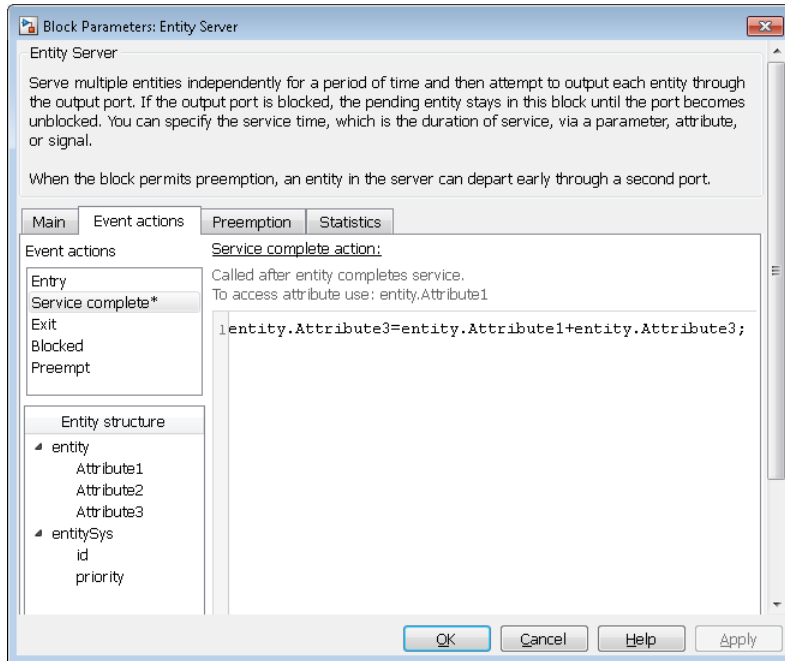
- 1 In a new model, from the SimEvents library, drag the Entity Generator, Entity Servern, and Entity Terminator blocks and connect them.



- 2 Double-click **Entity Generator** and, in the **Entity type** tab, add three attributes to the attributes table.

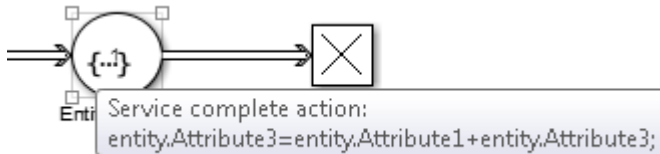


- 3 In the **Entity Server** block, click the **Entity actions** tab.
- 4 For the **Service complete** action, enter MATLAB code to manipulate the entity attributes you added in the **Entity Generator** block. For example:



This code updates the Entity Server block with the event action icon.

- 5 To see the action, in the model, hover over the Entity Server block event action icon block.



See Also

Discrete Event Chart | Entity Generator | MATLAB Discrete Event System

Related Examples

- “Manipulate Entity Attributes” on page 1-26

More About

- “What Is an Entity?”
- “Working with Entity Attributes” on page 1-23
- “Attribute Value Support” on page 1-35

Inspect Structures of Entities

You can inspect entity structures using these methods:

- On a signal line, using the Signal Hierarchy Viewer (for more information, see “Display Entity Types” on page 1-30).
- In a block at run-time, using the Entity Inspector

In this section...

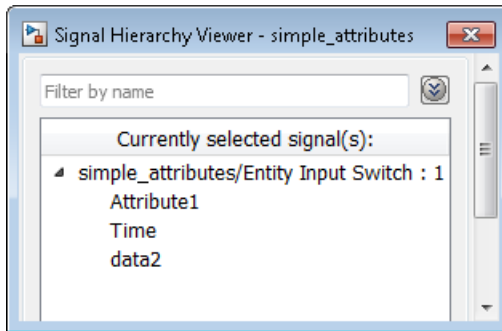
“Display Entity Types” on page 1-30

“Inspect Entities at Run Time” on page 1-31

Display Entity Types

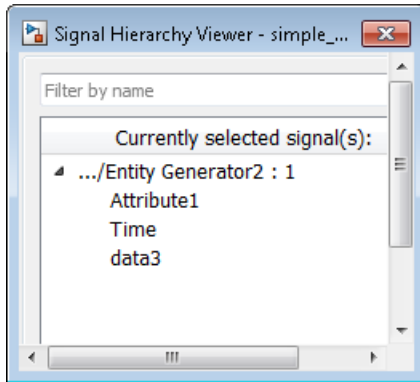
To show entity types in your model, in the model editor, right-click a line and select **Signal Hierarchy**. The Signal Hierarchy Viewer interactively displays about entities, signals, and bus objects. For more information on the Signal Hierarchy Viewer, see “Signal Hierarchy Viewer”.

If you have configured any blocks to receive an entity structure that the preceding block does not provide, upon compilation, the software automatically displays entity types. This behavior helps you to troubleshoot the mismatch in entity structures before simulation. The software displays an approximate list of the entity types and attributes. Use this as a guideline and not as a definitive list.



If entities on two separate paths have the same structure throughout the model, you can use the same entity type for both entity paths.

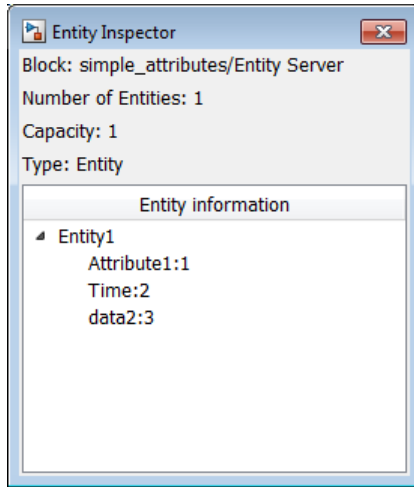
If you now modify the second Entity Generate block path to change data2 to data3, the structure of entities on the second path becomes unique. You must specify a new entity type name for the second Entity Generator block.



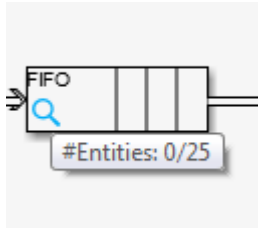
Inspect Entities at Run Time

To inspect entities at run-time, use the Entity Inspector. Inspect entities and their attribute values in a block.

- 1 In a SimEvents model, use the Simulink Simulation Stepper to step through the model.
- 2 As you step through the model, each block with entities updates to contain a magnifying glass.
- 3 To display entity details, including attributes, click the magnifying glass.



- 4 To see the number of entities, hover over the magnifying glass.



Alternatively, use the SimEvents Debugger to inspect entities. For more information, see [SimEvents Debugger](#).

See Also

[Entity Generator](#) | [SimEvents Debugger](#)

More About

- “What Is an Entity?”
- “Entity Types” on page 1-2
- “Role of Entity Ports and Paths”
- “Attribute Value Support” on page 1-35

Combine Entities

You can combine entities from different paths using the **Composite Entity Creator** block. The entities that you combine, called component entities, might represent different parts within a larger item, such as the header, payload, and trailer that are parts of a data packet. Alternatively, you can model resource allocation by combining an entity that represents a resource with an entity that represents a part or other item.

The **Composite Entity Creator** block and its surrounding blocks automatically detect when all necessary component entities are present and when the composite entity that results from the combining operation will be able to advance to the next block.

The **Composite Entity Creator** block provides options for managing information (attributes and timers) associated with the component entities. You can also configure the **Composite Entity Creator** block to make the combining operation reversible via the **Composite Entity Splitter** block.

See Also

[Composite Entity Creator](#) | [Composite Entity Splitter](#) | [Entity Generator](#)

More About

- [“What Is an Entity?”](#)

Replicate Entities on Multiple Paths

The **Entity Replicator** block enables you to distribute copies of an entity on multiple entity paths. Replicating entities might be a requirement of the situation you are modeling. For example, copies of messages in a multicasting communication system can advance to multiple transmitters or multiple recipients.

Similarly, copies of computer jobs can advance to multiple computers in a cluster so that the jobs can be processed in parallel on different platforms.

In some cases, replicating entities is a convenient modeling construct.

Modeling Notes

- Unlike the **Entity Output Switch** block, the **Entity Replicator** block has departures at all of its entity output ports that are not blocked, not just a single selected entity output port.
- If your model routes the replicates such that they use a common entity path, then be aware that blockages can occur during the replication process. For example, if you have this scenario:
 - An **Entity Replicator** block has the **Replicas depart from** parameter set to **Separate output ports**.
 - The block has these output ports connected to individual **Entity Server** blocks.

A blockage can occur because the servers can accommodate at most one of the replicates at a time. The blockage causes fewer than the maximum number of replicates to depart from the block.

- Each time the **Entity Replicator** block replicates an entity, the copies depart in a sequence whose start is determined by the **Hold original entity until all replicas depart** parameter. Although all copies depart at the same time instant, the sequence might be significant in some modeling situations. For details, see the reference page for the **Entity Replicator** block.

See Also

Entity Generator | Entity Replicator

More About

- “What Is an Entity?”

Attribute Value Support

These lists summarize the characteristics of attribute values for structured entity types.

Permitted Characteristics of Attribute Values

- Real or complex
- Array of any dimension, where the dimensions remain fixed throughout the simulation
- All built-in data types (`double`, `single`, `int8`, `uint8`, `int16`, `uint16`, `int32`, and `uint32`)
- Enumerations

For a given attribute, the characteristics of the value must be consistent throughout the discrete-event system in the model.

Not Permitted as Attribute Values

- Structure
- Bus
- Variable-size signals or variable-size arrays
- Frame

See Also

Discrete Event Chart | Entity Generator | MATLAB Discrete Event System

Related Examples

- “Manipulate Entity Attributes” on page 1-26

More About

- “What Is an Entity?”
- “Working with Entity Attributes” on page 1-23

Modeling Queues and Servers

- “Model Basic Queuing Systems” on page 2-2
- “Sort by Priority” on page 2-4
- “Task Preemption in a Multitasking Processor” on page 2-6
- “Determine Whether a Queue Is Nonempty” on page 2-9
- “Model Server Failure” on page 2-10

Model Basic Queuing Systems

In this section...
“Example of a Logical Queue” on page 2-2
“Vary the Service Time of a Server” on page 2-2

Example of a Logical Queue

Suppose that you are modeling a queue that can physically hold 100 entities and you want to determine what proportion of the time the queue length exceeds 10. You can model the long queue as a pair of shorter queues connected in series. The shorter queues have length 90 and 10.

Although the division of the long queue into two shorter queues has no basis in physical reality, it enables you to gather statistics related to one of the shorter queues. In particular, you can view the queue length (**n**) of the queue having length 90. If the signal is positive over a nonzero time interval, then the length-90 queue contains an entity that cannot advance to the length-10 queue. This means that the length-10 queue is full. As a result, the physical length-100 queue contains more than 10 items. Determining the proportion of time the physical queue length exceeds 10 is equivalent to determining the proportion of time the queue length signal of the logical length-90 queue exceeds 0.

Vary the Service Time of a Server

You can vary the service time of a server using one of the following methods:

- Constant source, where you vary the constant
- Randomized source
- Arbitrary source
- Time-based source

Use the **Service time source** parameter of the Entity Server block to apply these methods. You can select from:

- Dialog

Enter the constant value in the **Service time value** parameter.

- Signal port

Connect a time source to the resulting signal port.

- **Attribute**

Enter the name of the attribute that contains data to be interpreted as service.

- **MATLAB action**

In the **Service time action** section, enter MATLAB code to vary the service time. Assign the variable dt , which the model uses as service time.

See Also

Entity Queue | Entity Server

Related Examples

- “Sort by Priority” on page 2-4
- “Task Preemption in a Multitasking Processor” on page 2-6
- “Determine Whether a Queue Is Nonempty” on page 2-9
- “Model Server Failure” on page 2-10

More About

- “Storage”

Sort by Priority

In this section...

“Behavior of Priority Mode of Entity Queue Block ” on page 2-4

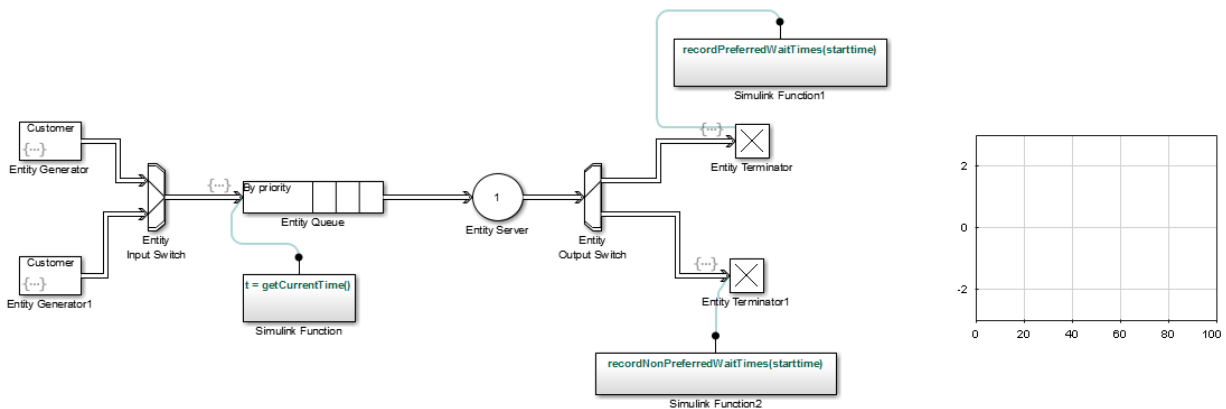
“Serve Preferred Customers First” on page 2-4

Behavior of Priority Mode of Entity Queue Block

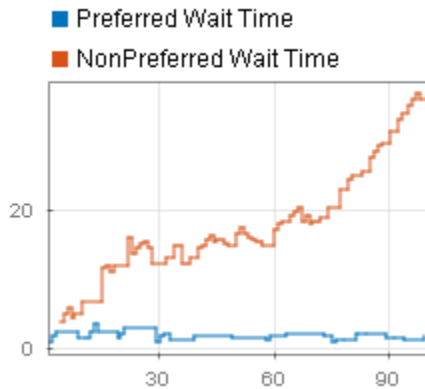
The **Priority** mode of the **Entity Queue** block supports queuing in which entities positions in the queue are based primarily on specific attribute values. Arrival times are relevant only when attribute values are equal. You specify the attribute and the sorting direction using the **Priority source** and **Sorting direction** parameters in the block dialog box.

Serve Preferred Customers First

In this example, two types of customers enter a queuing system. One type, considered to be preferred customers, are less common but require longer service. The priority queue places preferred customers ahead of nonpreferred customers. The model plots the average system time for the set of preferred customers and separately for the set of nonpreferred customers in a **Dashboard Scope** block.



You can see from the plots that despite the shorter service time, the average system time for the nonpreferred customers is much longer than the average system time for the preferred customers.



Comparison with Unsorted Behavior

If the queue used a FIFO discipline for all customers instead of a priority sorting, then the average system time would decrease slightly for the nonpreferred customers and increase markedly for the preferred customers.

See Also

Entity Queue | Entity Server

Related Examples

- “Model Basic Queuing Systems” on page 2-2
- “Task Preemption in a Multitasking Processor” on page 2-6
- “Determine Whether a Queue Is Nonempty” on page 2-9
- “Model Server Failure” on page 2-10

More About

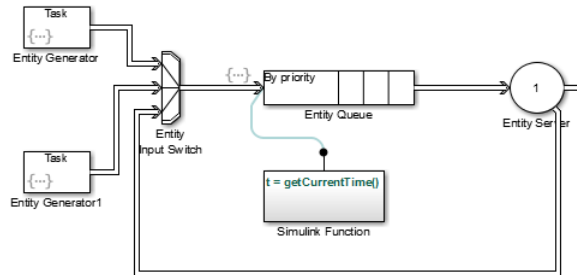
- “Storage”

Task Preemption in a Multitasking Processor

This example shows how to force service completion in an **Entity Server** block using functionality available on the block **Preemption** tab.

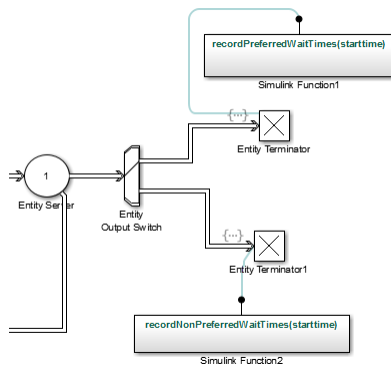
The example shows preemption—replacement—of low priority tasks by a high priority task in a multitasking processor. An **Entity Server** block represents the task processor presented with a capacity to process multiple concurrent tasks.

The following graphic shows how the model generates both low and high priority tasks.



- The top and bottom **Entity Generator** randomly generate entities that represent high and low priority tasks, respectively. Both blocks use the `exprnd` function to generate random entities. The top block uses `exprnd(3)`, the bottom uses `exprnd(1)`, which requires the Statistics and Machine Learning Toolbox™ license.
- The **Entity Input Switch** block merges the paths of the new low priority tasks with previously preempted tasks that are returning from the task processor (server).
- The **Simulink Function** block runs the `getCurrentTime` function to start a timer on the low priority tasks. When preemption occurs, a downstream **Simulink Function** block determines the remaining service time of the preempted tasks.
- The **Entity Output Switch** block merges the paths of the high and low priority tasks. Tasks on the merged path proceed for processing.

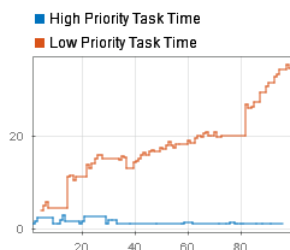
An **Entity Server** block represents a multitasking processor with capacity for multiple tasks.



When preemption occurs, causing the Entity Server block to complete immediately service of all low priority tasks, one of the two Simulink Function blocks calculates the elapsed time of each departing task using the `recordPreferredWaitTimes` and `recordNonPreferredWaitTimes` functions. The two Entity Terminator blocks calls these Simulink Function to calculate the elapsed times.

If the elapsed time of a departing task is less than the service time of the Entity Server block, meaning that preemption forced the task to depart the server early, the Output Switch block feeds the task back to reenter the server. If the elapsed time in the Simulink Function `getCurrentTime` block is *equal* to the service time of the Entity Server block, the server has completed the full service time on the task. The entity terminates in the Entity Terminator block.

The scope plots show the simulation results.



See Also

Entity Queue | Entity Server

Related Examples

- “Model Basic Queuing Systems” on page 2-2
- “Sort by Priority” on page 2-4
- “Determine Whether a Queue Is Nonempty” on page 2-9
- “Model Server Failure” on page 2-10

More About

- “Storage”

Determine Whether a Queue Is Nonempty

To determine whether a queue is storing any entities, use this technique:

- 1 Enable the **n** output signal from the queue block. In the block dialog box, on the **Statistics** tab, select the **Number of entities in block, n** check box.
- 2 From the Sinks library in the Simulink library set, insert a **Scope** block into the model. Connect the **n** output port of the queue block to the input port of the **Scope** block.

The scope shows if the queue is empty.

See Also

Entity Queue | Entity Server

Related Examples

- “Model Basic Queuing Systems” on page 2-2
- “Sort by Priority” on page 2-4
- “Task Preemption in a Multitasking Processor” on page 2-6
- “Model Server Failure” on page 2-10

More About

- “Storage”

Model Server Failure

In this section...

“Server States” on page 2-10

“Use a Gate to Implement a Failure State” on page 2-10

Server States

In some applications, it is useful to model situations in which a server fails. For example, a machine breaks down and later is repaired, or a network connection fails and later is restored. This section explores ways to model failure of a server, and server states.

Server blocks do not have built-in states, so you can design states in any way that is appropriate for your application. Some examples of possible server states are in this table.

Server as Communication Channel	Server as Machine	Server as Human Processor
Transmitting message	Processing part	Working
Connected but idle	Waiting for new part to arrive	Waiting for work
Unconnected	Off	Off duty
Holding message (pending availability of destination)	Holding part (pending availability of next operator)	Waiting for resource
Establishing connection	Warming up	Preparing to begin work

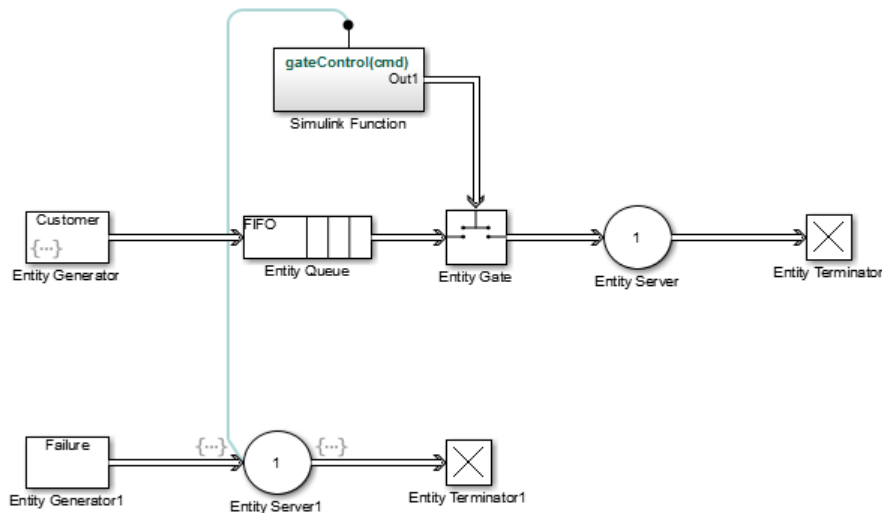
Use a Gate to Implement a Failure State

For any state that represents a server inability or refusal to accept entity arrivals even though the server is not necessarily full, a common implementation involves an **Entity Gate** block preceding the server.

The gate prevents entity access to the server whenever the gate control message at the inport port at the top of the block carries zero or negative values. The logic that creates the control message determines whether the server is in a failure state. You can

implement such logic using the Simulink Function block, using a Message Send block, or using Stateflow charts to transition among a finite number of server states.

This example shows an instance in which an Entity Gate block precedes a server. The example is not specifically about a failure state, but the idea of controlling access to a server is similar. It models a stochastically occurring failure that lasts for some amount of time.



Note: A gate prevents new entities from arriving at the server but does not prevent the current entity from completing its service. If you want to eject the current entity from the server upon a failure occurrence, then you can use the preemption feature of the server to replace the current entity with a high-priority “placeholder” entity.

See Also

Entity Queue | Entity Server

Related Examples

- “Model Basic Queuing Systems” on page 2-2
- “Sort by Priority” on page 2-4

- “Task Preemption in a Multitasking Processor” on page 2-6
- “Determine Whether a Queue Is Nonempty” on page 2-9

More About

- “Storage”

Routing Techniques

- “Role of Paths in SimEvents Models” on page 3-2
- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12
- “Use Attributes to Route Entities” on page 3-15
- “Role of Gates in SimEvents Models” on page 3-16
- “Enable a Gate for a Time Interval” on page 3-18

Role of Paths in SimEvents Models

In this section...
“Definition of Entity Paths” on page 3-2
“Implications of Entity Paths” on page 3-2
“Overview Blocks for Designing Paths” on page 3-2

Definition of Entity Paths

An entity path is a connection from an entity output port to an entity input port, depicted as a line connecting the entity ports of two SimEvents blocks. An entity path represents the equivalence between an entity's departure from the first block and arrival at the second block. For example, any entity that departs from the output port of an **Entity Queue** block set to FIFO mode equivalently arrives at an **Entity Server** block input port.

The existence of the entity path does not guarantee that any entity actually uses the path; for example, the simulation could be so short that no entities are ever generated. Even when an entity path is used, it is used only at a discrete set of times during the simulation.

Implications of Entity Paths

In some models, you can use the entity connection lines to infer the full sequence of blocks that a given entity arrives at, throughout the simulation.

In many discrete-event models, however, the set of entity connection lines does not completely determine the sequence of blocks that each entity arrives at.

By looking at entity connection lines alone, you cannot tell which queue block's input port an entity will arrive at. Instead, you need to know more about how the **Entity Output Switch** block behaves and you might even need to know the outcome of certain run-time decisions.

Overview Blocks for Designing Paths

You design entity paths by choosing or combining entity paths using these blocks:

- Entity Input Switch

- Entity Output Switch
- Entity Replicator

These blocks have extra entity ports that let you vary the model's topology (that is, the set of blocks and connection lines).

Typical reasons for manipulating entity paths are

- To describe an inherently parallel behavior in the situation you are modeling — for example, a computer cluster with two computers that share the computing load. You can use the **Entity Output Switch** block to send computing jobs to one of the two computers. You might also use the **Entity Input Switch** block if computing jobs share a common destination following the pair of computers.
- To design nonlinear topologies, such as feedback loops — for example, repeating an operation if quality criteria such as quality of service (QoS) are not met. You can use the **Entity Input Switch** block to combine the paths of new entities and entities that require a repeated operation.
- To incorporate logical decision making into your simulation — for example, determining scheduling protocols. You might use the **Entity Input Switch** block to determine which of several queues receives attention from a server.

Other blocks in the SimEvents library have secondary features, such as preemption from a server, that give you opportunities to design paths.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12
- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Use Attributes to Route Entities” on page 3-15

- “Role of Gates in SimEvents Models” on page 3-16

Select Departure Path Using Entity Output Switch

In this section...

“Role of the Entity Output Switch” on page 3-5

“Sample Use Cases” on page 3-5

“Select the First Available Server” on page 3-6

“Use an Attribute to Select an Output Port” on page 3-6

Role of the Entity Output Switch

The Entity Output Switch block selects one among a number of entity output ports. The selected port can change during the simulation. You have several options for criteria that the block uses to select an entity output port.

When the selected port is not blocked, an arriving entity departs through this port.

Sample Use Cases

Here are some scenarios in which you might use an output switch:

- Entities advance to one of several queues based on efficiency or fairness concerns. For example, airplanes advance to one of several runways depending on queue length, or customers advance to the first available cashier out of several cashiers.

Comparing different approaches to efficiency or fairness, by testing different rules to determine the selected output port of the output switch, might be part of your goal in simulating the system.

- Entities advance to a specific destination based on their characteristics. For example, parcels advance to one of several delivery vehicles based on the locations of the specified recipients.
- Entities use an alternate route in case the preferred route is blocked. For example, a communications network drops a packet if the route to the transmitter is blocked and the simulation gathers statistics about dropped packets.

The topics listed below illustrate the use of the Entity Output Switch block.

Topic	Features of Example
“Select the First Available Server” on page 3-6	First port that is not blocked switching criterion
“Use an Attribute to Select an Output Port” on page 3-6	Attribute-based switching, where the attribute value is random

Select the First Available Server

Assume an example where entities arriving at the Entity Output Switch block depart through the first entity output port that is not blocked, as long as at least one entity output port is not blocked. An everyday example of this approach is a single queue of people waiting for service by one of several bank tellers, cashiers, call center representatives, etc. Each person in the queue wants to advance as soon as possible to the first available service provider without preferring one over another.

You can implement this approach by setting the **Switching criterion** parameter in the Entity Output Switch block to **First port that is not blocked**.

Use an Attribute to Select an Output Port

Consider the situation in which parcels are sorted among several delivery vehicles based on the locations of the specified recipients. If each parcel is an entity, then you can attach data to each entity to indicate the location of its recipient. To implement the sorting, set the **Switching criterion** parameter in the Entity Output Switch block to **From attribute**.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12

- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Use Attributes to Route Entities” on page 3-15
- “Role of Gates in SimEvents Models” on page 3-16

Select Arrival Path Using Entity Input Switch

In this section...

“Role of the Input Switch” on page 3-8

“Round-Robin Approach to Choosing Inputs” on page 3-8

Role of the Input Switch

The Entity Input Switch chooses among a number of entity input ports. This block selects exactly one entity input port for potential arrivals and makes all other entity input ports unavailable. The selected entity input port can change during the simulation. You have several options for criteria that the block uses for selecting an entity input port.

A typical scenario in which you might use an input switch is when multiple sources of entities feed into a single queue, where the sequencing follows specific rules. For example, users of terminals in a time-shared computer submit jobs to a queue that feeds into the central processing unit, where an algorithm regulates access to the queue so as to prevent unfair domination by any one user.

Round-Robin Approach to Choosing Inputs

In a round-robin approach, an input switch cycles through the entity input ports in sequence. After the last entity input port, the next selection is the first entity input port. The switch selects the next entity input port after each entity departure. When the switch selects an entity input port, it makes the other entity input ports unavailable, regardless of how long it takes for an entity to arrive at the selected port.

You can implement a round-robin approach by

- 1 Setting the **Active port selection** parameter to **Switch**.
- 2 Setting the **Switching criterion** parameter to **Round robin**.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5

- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12
- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Use Attributes to Route Entities” on page 3-15
- “Role of Gates in SimEvents Models” on page 3-16

Combine Entity Paths

In this section...
“Using Entity Input Switch to Combine Paths” on page 3-10
“Sequence Simultaneous Pending Arrivals” on page 3-10

Using Entity Input Switch to Combine Paths

You can merge multiple paths into a single path using the **Entity Input Switch** block with the **Active port selection** parameter set to **All**. Merging entity paths does not change the entities themselves, just as merging lanes on a road does not change the vehicles that travel on it. In particular, the **Entity Input Switch** block does not create aggregates or batches.

Here are some scenarios in which you might combine entity paths:

- Attaching different data — Multiple entity generator blocks create entities having different values for a particular attribute. The entities then follow a merged path but might be treated differently later based on their individual attribute values.
- Merging queues — Multiple queues merge into a single queue.
- Connecting a feedback path — A feedback path enters the same queue as an ordinary path.

Sequence Simultaneous Pending Arrivals

The **Entity Input Switch** block does not experience any collisions, even if multiple entities attempt to arrive at the same time. The categories of behavior are as follows:

- If the entity output port is not blocked when the entities attempt to arrive, then the sequence of arrivals depends on the sequence of departure events from blocks that precede the **Entity Input Switch** block.

Even if the departure time is the same for multiple entities, the sequence might affect the system's behavior. For example, if the entities advance to a queue, the departure sequence determines their positions in the queue.

- If pending entities are waiting to advance to the **Entity Input Switch** block when its entity output port changes from blocked to unblocked, then the entity input ports

are notified of the change sequentially. The change from blocked to unblocked means that an entity can advance to the **Entity Input Switch** block.

If at least two entities are waiting to advance to the **Entity Input Switch** block via distinct entity input ports, then the notification sequence is important because the first port to be notified of the change is the first to advance an entity to the **Entity Input Switch** block.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Use Messages To Route Entities” on page 3-12
- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Use Attributes to Route Entities” on page 3-15
- “Role of Gates in SimEvents Models” on page 3-16

Use Messages To Route Entities

In this section...

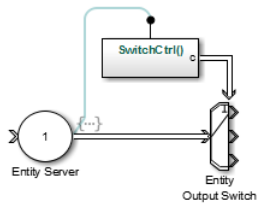
“Control Output Switch with a Message” on page 3-12

“Specify an Initial Port Selection” on page 3-13

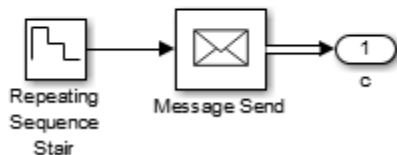
Control Output Switch with a Message

This example shows how to change the selected output port of an Entity Output Switch block to route entities along different paths. The software selects the path on a per-entity basis, not on a predetermined time schedule.

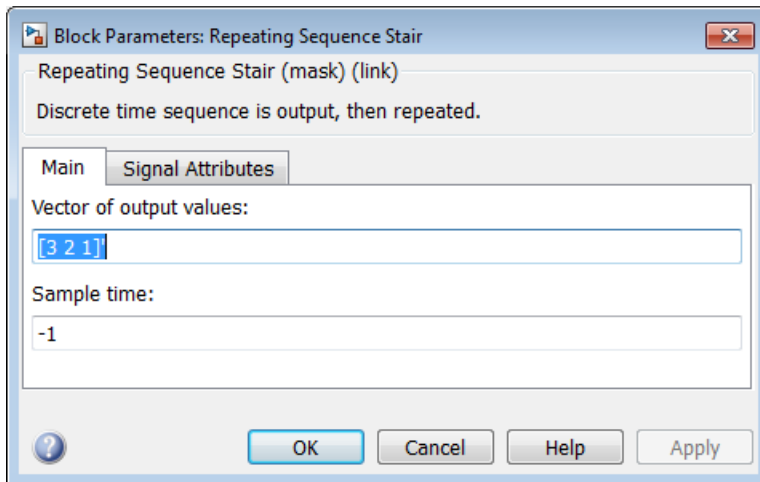
Consider the following example.



The SwitchCtrl function contains a single Repeating Sequence Stair block, whose **Sample time** parameter is set to -1 (inherited).



When the Simulink Function block executes, it outputs the next number from a repeating sequence. In this model, the output message value is 3, 2 or 1, based on the sequence of values specified in the Repeating Sequence Stair block.



When service in the Entity Server block is complete, the entity advances to the Entity Output Switch block. The output message of the Simulink Function block determines which output port the entity uses when it departs the Entity Output Switch block.

Specify an Initial Port Selection

When the Entity Output Switch block uses an input message, the block might attempt to use the message before its first sample time hit. If the initial value of the message is out of range (for example, it is unavailable). You should then specify the initial port selection in the Entity Output Switch block's dialog box. Use this procedure:

- 1 Select **From control port**.
- 2 Set **From control port** to the desired initial port selection. The value must be an integer between 1 and **Number of output ports**. The Entity Output Switch block uses **Initial port selection** until the first control port message arrives.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Use Attributes to Route Entities” on page 3-15
- “Role of Gates in SimEvents Models” on page 3-16

Use Attributes to Route Entities

Suppose entities represent manufactured items that undergo a quality control process followed by a packaging process. Items that pass the quality control test proceed to one of three packaging stations, while items that fail the quality control test proceed to one of two rework stations. You can model the decision making using these switches:

- An **Entity Output Switch** block that routes items based on an attribute that stores the results of the quality control test
- An **Entity Output Switch** block that routes passing-quality items to the packaging stations
- An **Entity Output Switch** block that routes failing-quality items to the rework stations

You can use the block **Switching criterion** parameter `From attribute` option to use an attribute to select the output port.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12
- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Role of Gates in SimEvents Models” on page 3-16

Role of Gates in SimEvents Models

In this section...
“Overview of Gate Behavior” on page 3-16
“Gate Behavior” on page 3-16

Overview of Gate Behavior

By design, certain blocks change their availability to arriving entities depending on the circumstances. For example,

- A queue or server accepts arriving entities as long as it is not already full to capacity.
- An input switch accepts an arriving entity through a single selected entity input port but forbids arrivals through other entity input ports.

Some applications require more control over whether and when entities advance from one block to the next. A gate provides flexible control via its changing status as either open or closed: by definition, an open gate permits entity arrivals as long as the entities would be able to advance immediately to the next block, while a closed gate forbids entity arrivals. You configure the gate so that it opens and closes under circumstances that are meaningful in your model.

For example, you might use a gate

- To create periods of unavailability of a server. For example, you might be simulating a manufacturing scenario over a monthlong period, where a server represents a machine that runs only 10 hours per day. An enabled gate can precede the server, to make the server's availability contingent upon the time.
- To make departures from one queue contingent upon departures from a second queue. A release gate can follow the first queue. The gate's control input determines when the gate opens, based on decreases in the number of entities in the second queue.
- With the **First port that is not blocked** mode of the **Entity Output Switch** block. Suppose each entity output port of the switch block is followed by a gate block. An entity attempts to advance via the first gate; if it is closed, then the entity attempts to advance via the second gate, and so on.

Gate Behavior

The **Entity Gate** block offers these fundamentally different kinds of gate behavior:

- The enabled gate, which uses a control signal to determine time intervals over which the gate is open or closed
- The release gate, which uses a control message to determine a discrete set of times at which the gate is instantaneously open. The gate is closed at all other times during the simulation.

Tip Many models follow a gate with a storage block, such as a queue or server.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12
- “Enable a Gate for a Time Interval” on page 3-18

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Use Attributes to Route Entities” on page 3-15

Enable a Gate for a Time Interval

In this section...
“Behavior of Entity Gate Block” on page 3-18
“Control Joint Availability of Two Servers” on page 3-18

Behavior of Entity Gate Block

The **Entity Gate** block uses a control signal at the input port labeled **en** to determine when the gate is open or closed:

- When a message with a positive payload arrives at the enable port at the top of the block, the gate is open and an entity can arrive as long as it would be able to advance immediately to the next block.
- When a message with zero or negative payload arrives at the enable port at the top of the block, the gate is closed and no entity can arrive.

Because the **en** signal can remain positive for a time interval of arbitrary length, an enabled gate can remain open for a time interval of arbitrary length. The length can be zero or a positive number.

Depending on your application, the gating logic can arise from time-driven dynamics, state-driven dynamics, a **SimEvents** block's statistical output signal, or a computation involving various types of signals.

Control Joint Availability of Two Servers

Suppose that each entity undergoes two processes, one at a time, and that the first process does not start if the second process is still in progress for the previous entity. Assume for this example that it is preferable to model the two processes using two **Single Server** blocks in series rather than one **Single Server** block whose service time is the sum of the two individual processing times; for example, you might find a two-block solution more intuitive or you might want to access the two **Single Server** blocks' utilization output signals independently in another part of the model.

If you connect a queue, a server, and another server in series, then the first server can start serving a new entity while the second server is still serving the previous entity. This does not accomplish the stated goal. The model needs a gate to prevent the first

server from accepting an entity too soon, that is, while the second server still holds the previous entity.

See Also

Entity Gate | Entity Input Switch | Entity Output Switch | Entity Replicator

Related Examples

- “Select Departure Path Using Entity Output Switch” on page 3-5
- “Select Arrival Path Using Entity Input Switch” on page 3-8
- “Combine Entity Paths” on page 3-10
- “Use Messages To Route Entities” on page 3-12

More About

- “Role of Paths in SimEvents Models” on page 3-2
- “Use Attributes to Route Entities” on page 3-15
- “Role of Gates in SimEvents Models” on page 3-16

Work with Resources

- “Model with Resources” on page 4-2
- “Set Resource Amount with Attributes” on page 4-4

Model with Resources

In this section...

“Resource Blocks” on page 4-2

“Resource Creation Workflow” on page 4-2

Resource Blocks

For an introduction to resources, see “Entity Resources”. The SimEvents software supplies the following resource allocation blocks:

Action	Block
Acquire resource	Resource Acquirer
Define resource	Resource Pool
Release resource	Resource Releaser

Resource Creation Workflow

- 1 Specify resources using the **Resource Pool** block. Define one resource per **Resource Pool** block. Multiple **Resource Pool** blocks can exist in the model with multiple entities sharing the resources.
- 2 Identify resources to be used with the **Resource Acquirer** block. You can identify these resources before specifying them in a **Resource Pool** block, or select them from the available resources list. However, the resource definitions must exist by the time you simulate the model. Multiple **Resource Acquire** blocks can exist in the model.
- 3 To release resources, include one or more **Resource Releaser** blocks. You can configure **Resource Release** blocks to release some or all resources for an entity. Alternatively, you can release all resources for an entity directly using the **Entity Terminator** block.

Tip To determine how long an entity holds a resource, insert a server block before the **Resource Acquire** block. In the **Service time** parameter, enter how long you want the entity to hold the resource.

An entity implicitly releases held resources when it:

- Is destroyed.
- Enters an **Entity Replicator** block and the block creates multiple copies of that entity.
- Is combined with other entities using the **Composite Entity Creator** block.
- Is split into its component entities using the **Composite Entity Splitter** block.

See Also

Resource Acquirer | Resource Pool | Resource Releaser

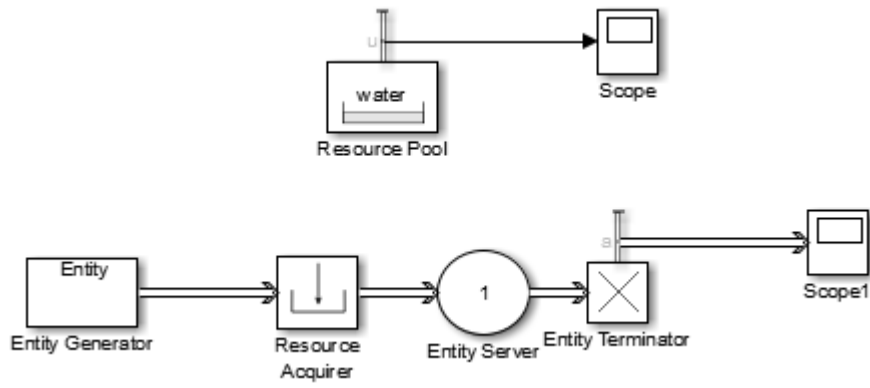
Set Resource Amount with Attributes

Use the **Selected Resources** table of the **Resource Acquirer** block to receive the resource amount definition from the block dialog box or an entity attribute. Using attributes as the source for the resource requires synchronicity between these blocks:

- **Entity Generator** block with the attribute definition that **Resource Acquirer** wants to supply the source amount
- **Resource Pool** block that defines the resource
- **Resource Acquirer** block that acquires the resource

This example shows this synchronicity.

- 1 Open a new model and add **Resource Pool**, **Entity Generator**, and **Resource Acquirer** blocks. For the **Resource Pool** block:
 - Set **Resource name** to **water**.
 - Set **Resource amount** to **20**.
 - In the **Statistics** tab, select **Amount in use, #u**.
- 2 In the **Entity Generator** block dialog box, click the **Entity type** tab and in the **Define attributes** table:
 - Enter the attribute name, **water_amount**, to indicate that the attribute defines the amount of the resource.
 - Set the value to **10**.
- 3 In the **Resource Acquirer** block dialog box, click the **Entity type** tab and under **Available Resources**, select **water** and move it to the **Selected Resources** table.
- 4 In the **Selected Resources** table, in the **water** entry:
 - For **Amount Source**, select **Attribute**.
 - For **Amount**, enter **water_amount** to match the attribute name defined in the **Entity Generator** block.
- 5 To complete the model, add the following blocks and connect them as shown in the figure:
 - **Entity Terminator** (select the **Statistics** tab **Number of entities arrived, #a** check box)
 - Two **Scope** blocks



6 Simulate the model and observe the amount of resources in use (Scope).

See Also

Resource Acquirer | Resource Pool | Resource Releaser

Visualization, Statistics, and Animation

- “Use Statistics to Understand SimEvents Models” on page 5-2
- “Access Statistics from SimEvents Blocks” on page 5-5
- “Visualization and Animation” on page 5-8

Use Statistics to Understand SimEvents Models

In this section...
“Statistics for Data Analysis” on page 5-2
“Statistics for Run-Time Control” on page 5-3
“Statistical Tools for Discrete-Event Simulation” on page 5-3

Statistics for Data Analysis

The purpose of creating a discrete-event simulation is often to improve understanding of the underlying system or guide decisions about the underlying system. Numerical results gathered during simulation can be important tools. For example:

- If you simulate the operation and maintenance of equipment on an assembly line, you might use the computed production and defect rates to help decide whether to change your maintenance schedule.
- If you simulate a communication bus under varying bus loads, you might use computed average delays in high- or low-priority messages to help determine whether a proposed architecture is viable.

When you design the statistical measures that you use to learn about the system, consider these questions:

- Which statistics are meaningful for your investigation or decision? For example, if you are trying to maximize efficiency, then what is an appropriate measure of efficiency in your system? As another example, does a mean give the best performance measure for your system, or is it also worthwhile to consider the proportion of samples in a given interval?
- How can you compute the desired statistics? For example, do you need to ignore any transient effects, does the choice of initial conditions matter, and what stopping criteria are appropriate for the simulation?
- To ensure sufficient confidence in the result, how many simulation runs do you need? One simulation run, no matter how long, is still a single sample and probably inadequate for valid statistical analysis.

For details concerning statistical analysis and variance reduction techniques, see the works [7], [4], [1], and [2].

Statistics for Run-Time Control

Some systems rely on statistics to influence the dynamics. For example, a queuing system with discouraged arrivals has a feedback loop that adjusts the arrival rate throughout the simulation based on statistics reported by the queue and server.

When you create simulations that use statistical signals to control the dynamics, you must have access to the current values of the statistics at key times throughout the simulation, not just at the end of the simulation. Some questions to consider while designing your model are:

- Which statistics are meaningful, and how should they influence the dynamics of the system?
- How can you compute the desired statistics at the right times during the simulation? It is important to understand when SimEvents blocks update each of their statistical outputs and when other blocks can access the updated values.
- Will small perturbations result in large changes in the system behavior? When using statistics to control the model, you might want to monitor those statistics or other statistics to check whether the system is undesirably sensitive to perturbations.

Statistical Tools for Discrete-Event Simulation

The table lists components that SimEvents models commonly use to gather or compute statistics.

Statistical Information	Available Tools
Number of entities in a queue or server	n output signal from queue and server blocks
Utilization of a server	util output signal from Entity Server block
Number of entities that have departed from a block	<ul style="list-style-type: none"> • d output signal from various SimEvents blocks • Entity Generator • Entity Server • Entity Queue • Multicast Receive Queue • Resource Acquirer
Pending entity present in block	<ul style="list-style-type: none"> • pe output signal from various SimEvents blocks • Entity Generator

Statistical Information	Available Tools
	<ul style="list-style-type: none"> Entity Server
Number of entities arrived	a output signal from Entity Terminator block
Average wait	<ul style="list-style-type: none"> w output signal from various SimEvents blocks Entity Queue Entity Server Resource Acquirer
Average intergeneration time	w output signal from Entity Generator block
Average queue length	l output signal from Entity Queue block
Number of pending entities	np output signal from Entity Server block
Custom computation on event actions	<ul style="list-style-type: none"> Simulink Function MATLAB code

See Also

Entity Server | Entity Terminator | Entity Generator | Entity Queue | Entity Server | Multicast Receive Queue | Resource Acquirer

Related Examples

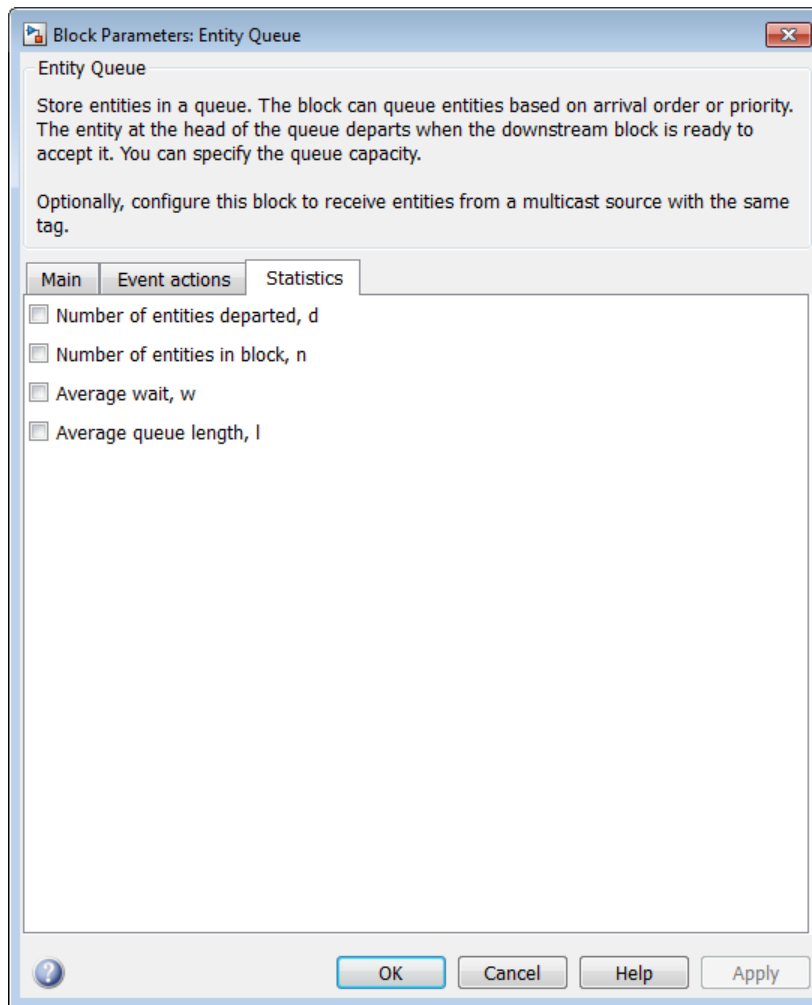
- “Access Statistics from SimEvents Blocks” on page 5-5

More About

- “Statistics Through SimEvents Blocks”
- “Count Entities”
- “Visualization and Animation” on page 5-8

Access Statistics from SimEvents Blocks

Most SimEvents blocks can produce one or more statistical output signals.



This procedure shows you how to access a statistical output signal for a given SimEvents block.

- 1 Determine which statistical output signal you want to access and find the associated parameter in the block dialog box. To see which statistics are available, open the block dialog box. Usually, the list of available statistics appears as a list of parameters on the **Statistics** tab of the dialog box. In cases where the dialog box has no **Statistics** tab, the dialog box has so few parameters that the parameters associated with statistics are straightforward to locate.
- 2 Select the check box. After you apply the change, the block has a new signal output port corresponding to that statistic.
- 3 Connect the new signal output port to the signal input port of another block. The table lists some common examples.

Note: Use scopes and other observer blocks to observe individual statistic ports. However, you cannot use the same scope to observe multiple statistics ports. To observe multiple statistic ports, consider using a dashboard or the Simulation Data Inspector.

If You Want to...	Use this Block...
Create a plot using the statistic.	Simulink Scope or dashboard
Show the statistic on the block icon throughout the simulation.	Simulation Data Inspector or Display
Write the data set to the MATLAB workspace when the simulation stops or pauses. To learn more, see “Save Simulation Data” on page 7-4.	Signal logging or To Workspace. In addition, you can also log signals observed using scopes and Simulation Data Inspector to the workspace.
Perform custom data processing. See “Derive Custom Statistics” on page 5-6 for some suggestions.	Custom subsystem or computational block

Derive Custom Statistics

You can use the built-in statistical signals from SimEvents blocks to derive more specialized or complex statistics that are meaningful in your model. One approach is to compute statistics during the simulation. You can implement your computations using a graphical block-diagram approach or a nongraphical coded approach. Alternatively, you can compute statistics using MATLAB code after the simulation is complete.

See Also

Entity Server | Entity Terminator | Entity Generator | Entity Queue |
Entity Server | Multicast Receive Queue | Resource Acquirer

Related Examples

- “Access Statistics from SimEvents Blocks” on page 5-5

More About

- “Statistics Through SimEvents Blocks”
- “Use Statistics to Understand SimEvents Models” on page 5-2
- “Count Entities”
- “Visualization and Animation” on page 5-8

Visualization and Animation

Visualize and animate simulations in SimEvents models using tools available in Simulink and SimEvents software.

- You can place many Simulink Sink blocks directly on the entity line to observe entities, including the `To Workspace` and dashboard scopes.
- If the entity type is anonymous, you can place a `Scope` block.
- To observe bus or structured type entities, use the Simulation Data Inspector or dashboard scopes. The `Scope` and `Display` blocks do not support buses.

See Also

`Entity Server` | `Entity Terminator` | `Entity Generator` | `Entity Queue` | `Entity Server` | `Multicast Receive Queue` | `Resource Acquirer`

Related Examples

- “Access Statistics from SimEvents Blocks” on page 5-5
- “Visualize and Animate Simulations”

More About

- “Statistics Through SimEvents Blocks”
- “Count Entities”

Learning More About SimEvents Software

- “Event Calendar” on page 6-2
- “Entity Priorities” on page 6-3
- “Livelock Prevention” on page 6-5
- “Storage and Nonstorage Blocks” on page 6-6

Event Calendar

During a simulation, the model maintains a list, called the event calendar, of upcoming events that are scheduled for the current simulation time or future times. The event calendar sorts multiple events that are scheduled for the same time by the priority of the entity for which they are scheduled. The model refers to the event calendar to execute events at the correct simulation time and in an appropriately prioritized sequence.

These are the events that the event calendar tracks.

Event	For Blocks
Generate	Entity Generator, MATLAB Discrete-Event System
Forward	Entity Generator, Entity Queue, Multicast Receive Queue, Entity Server, Entity Terminator, Discrete Event Chart, MATLAB Discrete Event System, Entity Replicator, Resource Acquirer
ServiceComplete	Entity Server
Timer	MATLAB Discrete-Event System, Discrete Event Chart
Iterate	MATLAB Discrete-Event System
Destroy	MATLAB Discrete-Event System

See Also

Discrete Event Chart | Entity Generator | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System | Multicast Receive Queue | Resource Acquirer

Entity Priorities

SimEvents software uses entity priorities to prioritize events. The smaller the priority value, the higher the priority.

You specify entity priorities when you generate entities. You can later change entity priorities using an event action for the priority. For example, in the **Entity Generator Event actions** tab, you can define an event action to change the entity priority during simulation using code such as:

```
entitySys.priority=MATLAB code
```

The event calendar includes event types such as:

- Entity generation
- Entity forwarding
- Entity destruction
- Timer
- Service completion

The event calendar sorts events based on times and associated entity priorities as outlined here:

- 1** The event that has the earliest time executes first.
- 2** If two entities have events occurring at the same time, the event with the entity of higher priority occurs first.
- 3** If both entities have the same priority, it is undefined which event is served first. To get deterministic order, change one of the entity priorities.

For example, assume a forward event associated with an entity that exits block *A* and enters block *B*. The priority of this event is the priority of the entity being forwarded. If there are two entities trying to depart a block at the same time, the entity with the higher priority departs first.

See Also

Discrete Event Chart | Entity Generator | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System | Multicast Receive Queue | Resource Acquirer

Related Examples

- “Sort by Priority” on page 2-4

Livelock Prevention

Large Finite Numbers of Simultaneous Events

Simultaneous events are events that occur at the same simulation clock time. If your simulation creates a large number of simultaneous events, this number might be an indication of an unwanted livelock situation. In this situation, a block returns to the same state infinitely often at the same time instant. SimEvents software prevents livelock with these limits:

- SimEvents software limits the maximum number of simultaneous events per block to 5,000.
- SimEvents software limits the maximum number of simultaneous events per model to 100,000.

More About

- “Information About Race Conditions and Random Times”

Storage and Nonstorage Blocks

In this section...
“Storage Blocks” on page 6-6
“Nonstorage Blocks” on page 6-6

Storage Blocks

These blocks are capable of holding an entity:

- Entity Generator
- Entity Queue
- Multicast Receive Queue
- Entity Server
- Entity Terminator
- Discrete Event Chart
- MATLAB Discrete Event System
- Entity Replicator
- Resource Acquirer

Nonstorage Blocks

These blocks permit an entity arrival but must output or destroy the entity at the same value of the simulation clock:

- Entity Input Switch
- Entity Output Switch
- Entity Multicast
- Entity Gate
- Composite Entity Creator
- Composite Entity Splitter
- Resource Releaser
- Resource Pool

See Also

Composite Entity Creator | Composite Entity Splitter | Discrete Event Chart | Entity Gate | Entity Generator | Entity Input Switch | Entity Multicast | Entity Output Switch | Entity Queue | Entity Replicator | Entity Server | Entity Terminator | MATLAB Discrete Event System | Multicast Receive Queue | Resource Acquirer | Resource Pool | Resource Releaser

Working with Simulink

- “Exchange Data Between SimEvents and Simulink” on page 7-2
- “Time-Based Signals and SimEvents Block Transitions” on page 7-3
- “Save Simulation Data” on page 7-4
- “Solvers for Discrete-Event Systems” on page 7-6
- “SimEvents Support for Simulink Subsystems” on page 7-9

Exchange Data Between SimEvents and Simulink

Use Simulink Function blocks in SimEvents models:

- To read or write attributes of entities.
- To send messages that trigger other events.
- To exchange data between event and time domain sections of a model.

Use the Message Send and Message Receive blocks to send and receive messages between Simulink and SimEvents blocks.

See Also

Message Receive | Message Send | Simulink Function

Related Examples

- “Events and Event Actions” on page 1-4
- “Generate Entities When Events Occur” on page 1-7

More About

- “What Is an Event?”

Time-Based Signals and SimEvents Block Transitions

When Signals Transition

Time-based signals and SimEvents signals have different characteristics. Here are some indications that a time-based signal will be automatically converted into a SimEvents signal, or vice versa:

- You want to connect a time-based signal to an input port of a SimEvents block.
- You are using data from a SimEvents block to affect time-based dynamics.
- You want to perform a computation involving both time-based signals and SimEvents output.

When the transition occurs, a capital **E** appears on the line.

More About

- “What Is an Entity?”

Save Simulation Data

In this section...

“Behavior of the To Workspace Block” on page 7-4

“Send Queue Length to the Workspace” on page 7-4

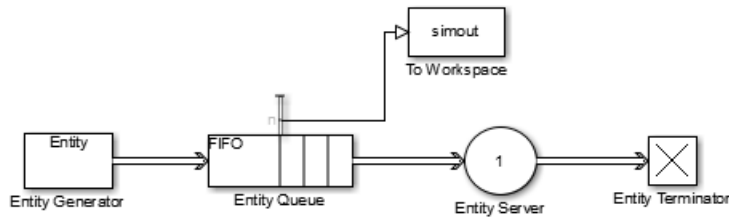
“Data Logging” on page 7-4

Behavior of the To Workspace Block

The To Workspace block writes event-based signals to the MATLAB workspace when the simulation stops or pauses. One way to pause a running simulation is to select **Simulation > Pause**.

Send Queue Length to the Workspace

The example shows one way to write the times and values of signals to the MATLAB workspace. In this case, the signal is the **n** output from an Entity Queue block, which indicates how many entities the queue holds.



You can use different time formats in the To Workspace block to display the data.

To record entities and their attributes passing along an entity line, consider connecting a To Workspace block to that entity line.

Data Logging

You can log data from your SimEvents model using Simulink. For more information, see “Save Runtime Data from Simulation”.

See Also

“Save Runtime Data from Simulation” | To Workspace

Solvers for Discrete-Event Systems

In this section...
“Variable-Step Solvers for Discrete-Event Systems” on page 7-6
“Fixed-Step Solvers for Discrete-Event Systems” on page 7-7

Depending on your configuration, you can use both variable-step and fixed-step solvers with discrete-event systems. To choose solver settings for your model, navigate to the **Solver** pane of the model Configuration Parameters dialog box.

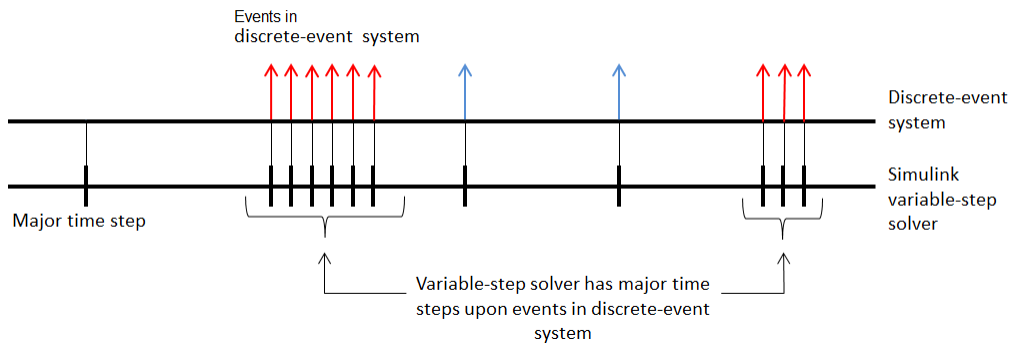
When choosing a solver type for your model, use the following guidelines:

- If your model contains only event-based computation and excludes continuous and discrete time-based computation, choose the variable-step, discrete solver. In this case, if you select a variable-step continuous solver, the software detects that your model does not contain any blocks with continuous states (Simulink blocks) and automatically switches the solver to **discrete (no continuous states)**. When the software makes this change, it notifies you with a message in the MATLAB command window.
- If your discrete-event system is within a Simulink model that also contains time-based modeling, choose either a variable-step or fixed-step solver, depending on your simulation requirements. For each solver type, the following sections describe the behavior of discrete-event systems when contained within such models.

Variable-Step Solvers for Discrete-Event Systems

If your discrete-event system is within a Simulink model that contains time-based modeling, and you choose a variable-step solver for the model, the Simulink solver has a major time step each time the discrete-event system needs to process events.

The following graphic illustrates the behavior of the variable-step solver when used with a discrete-event system contained within a Simulink model.

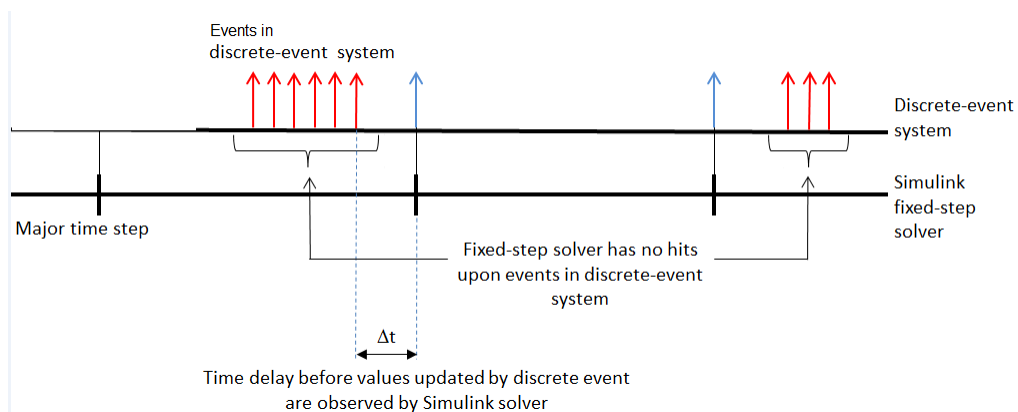


Fixed-Step Solvers for Discrete-Event Systems

If you have a discrete-event system within a Simulink model that includes time-based modeling, you can choose a fixed-step solver for the model.

When you use a fixed-step solver, the simulation still executes events in the discrete-event system at the times at which they occur. However, these events do not cause the Simulink solver to have sample hits at those times. The software insulates the discrete-event system from the time-based portions of the Simulink model.

The following graphic illustrates the behavior of the fixed-step solver when used with a discrete-event system.



More About

- “Solvers”

SimEvents Support for Simulink Subsystems

You can use SimEvents blocks (discrete-event blocks) without restriction in Simulink Virtual Subsystems, and in Simulink[®] Nonvirtual Subsystems, observing some specific guidelines.

For more information about Simulink subsystems, see “Systems and Subsystems”.

Discrete-Event Blocks in Virtual Subsystems

You can use discrete-event blocks without restriction in a virtual subsystem.

Discrete-Event Blocks in Nonvirtual Subsystems

For more information about atomic subsystems, see Subsystem, Atomic Subsystem, Nonvirtual Subsystem, CodeReuse Subsystem.

When you use discrete-event blocks in an atomic subsystem, follow these guidelines:

- The entire discrete-event subsystem, which includes all discrete-event blocks, must reside entirely within the atomic subsystem. You cannot route entities into, or out of, the atomic subsystem.
- If you want to connect two or more atomic subsystems that contain discrete-event blocks, each atomic subsystem must meet all the preceding conditions.

Discrete-Event Blocks in Variant Subsystems

You can use discrete-event blocks in a variant subsystem. The software permits both entities and time-based signals to enter and depart a virtual variant.

However, if you use an atomic subsystem as a variant, or within a variant, then that atomic subsystem must obey the rules for using discrete-event blocks in nonvirtual subsystems. These rules are described in “Discrete-Event Blocks in Nonvirtual Subsystems” on page 7-9. An atomic subsystem is the only type of nonvirtual subsystem that can contain discrete-event blocks, even when the nonvirtual subsystem is contained within a variant subsystem.

Variant System Support

The SimEvents software does not support the selection of the **Analyze all choices during update diagram and generate preprocessor conditionals** check box for these blocks:

- Variant Subsystem
- Variant Sink
- Variant Source

See Also

Atomic Subsystem | CodeReuse Subsystem | Nonvirtual Subsystem | Subsystem | Variant Source | Variant Sink | Variant Subsystem

More About

- “Systems and Subsystems”

Build Discrete-Event Systems Using Charts

- “Discrete-Event Systems Created with Stateflow Charts” on page 8-2
- “How Discrete-Event Charts Differ from Stateflow Charts” on page 8-3
- “Event Triggering in Discrete-Event Charts” on page 8-5

Discrete-Event Systems Created with Stateflow Charts

Why Use the Discrete Event Chart

A Stateflow discrete-event chart can receive, process, and send SimEvents entities. Using Stateflow discrete-event charts to create SimEvents systems lets you take advantage of:

- Graphical state transition and MATLAB action language used in Stateflow software
- Precise timing for temporal events arrival
- Triggering on message
- Dynamic event scheduling

Note: With SimEvents and its required software, you can view, edit, and simulate your Discrete Event Chart custom block within a SimEvents example model. However, to save the model you must have a Stateflow license.

For new models, without a Stateflow license, you can view and edit the model, but cannot simulate or save it.

The entities you use with discrete-event charts must be bus objects.

See Also

Discrete Event Chart

Related Examples

- “Specify Chart Properties”

More About

- “How Discrete-Event Charts Differ from Stateflow Charts” on page 8-3
- “Event Triggering in Discrete-Event Charts” on page 8-5

How Discrete-Event Charts Differ from Stateflow Charts

In this section...

“Discrete Event Chart Properties” on page 8-3

“Define Message (Entity) Input and Output” on page 8-4

“Define Local Messages” on page 8-4

“Specify Message Properties” on page 8-4

Discrete Event Chart Properties

Discrete event chart properties allow you to specify how your chart interfaces with the Simulink model.

Set Properties for a Chart

To specify properties for a single chart:

- 1 Double-click a chart.
- 2 Right-click an open area of the chart and select **Properties**.

All charts provide general and documentation properties.

- 3 Observe that the chart allows the configuration of only these properties on the **General** tab. It also supports the **Fixed-point properties** and **Documentation** tabs.

- **Name**
- **Machine**
- **Saturate on integer overflow**
- **Create data for monitoring**
- **Lock Editor**

Notes:

- SimEvents software supports only MATLAB action language
- SimEvents always supports variable-size arrays

Define Message (Entity) Input and Output

A discrete-event chart uses SimEvents entities the same way that Stateflow software uses messages. As with Stateflow charts, you can add message (entity) input and output using the Stateflow Editor or Model Explorer. Based on the desired scope, select one of the following options:

Scope	Menu Option
Input	Message (Entity) Input from Simulink
Output	Message (Entity) Output from Simulink

Define Local Messages

As with Stateflow charts, you can define local messages for the discrete-event chart using the Stateflow Editor or Model Explorer. To add a local message for the discrete-event chart, select **Chart > Add Other Elements > Local Message (Entity)...**

Specify Message Properties

Discrete-event charts have this additional property for output messages and local messages:

Message Input Port Properties	Description
Priority	If two message events occur at the same time, to decide which to process first, the discrete-event chart uses this priority. A smaller numeric value indicates a higher priority.

See Also

Discrete Event Chart

More About

- “Discrete-Event Systems Created with Stateflow Charts” on page 8-2
- “Event Triggering in Discrete-Event Charts” on page 8-5

Event Triggering in Discrete-Event Charts

In this section...

“Event Triggering” on page 8-5

“Message Triggering” on page 8-5

“Temporal Triggering” on page 8-5

Event Triggering

SimEvents discrete-event system charts support these events in the chart:

- Message event
- Temporal event
- Local event
- `enter`, `exit`, `on`, `change`

SimEvents discrete-event system charts do not support these events in the chart:

- Conditions without event
- `during`, `tick`
- Event input from Simulink
- Event output to Simulink

Message Triggering

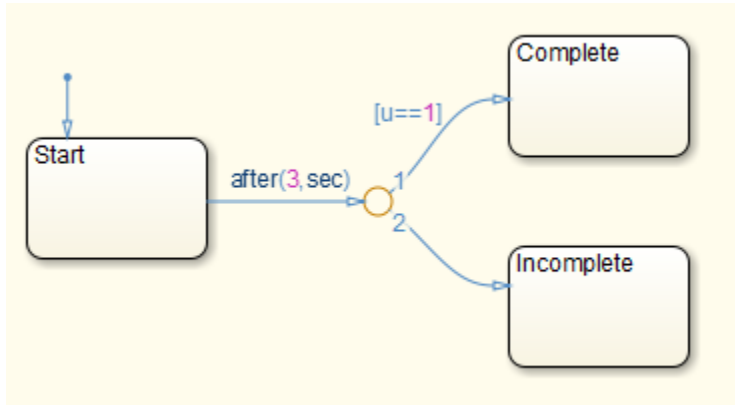
When a message arrives at a message input or local queue, the discrete-event chart responds to the message as follows:

- If the discrete-event chart is in a state of waiting for a message, the discrete-event chart wakes up and makes possible transitions. The chart immediately wakes up in order of message priority, processing the message with the highest priority first.
- If the discrete-event chart does not need to respond to the arriving message, the discrete-event chart does not wake up and the message is queued.

Temporal Triggering

In a discrete-event chart, you can use both event-based and absolute time-based temporal logic operators. When using absolute time-based temporal logic operators, the SimEvents

software honors the specified time delay value exactly. For example, the activation of the temporal logic 'after(3, sec)' causes the chart to wake up after three seconds of simulation clock time.



When using absolute-time temporal logic operators, observe these differences from the Stateflow environment.

Operator	Description
after	You can use as event notation in both state actions and transitions.
before	When you use as event notation of a transition, you cannot use additional condition notations on this transition. You can apply a connective junction to check additional conditions, as long as the connective junction has one unconditional transition.

In conditional notation, the software supports both **after** and **before**.

See Also

Discrete Event Chart

More About

- “Discrete-Event Systems Created with Stateflow Charts” on page 8-2

- “How Discrete-Event Charts Differ from Stateflow Charts” on page 8-3

Build Discrete-Event Systems Using System Objects

- “Discrete-Event Systems Created with a System Object” on page 9-2
- “Use a MATLAB Discrete-Event System Block” on page 9-5
- “Implement a Discrete-Event System Object” on page 9-7
- “Custom Entity Types, Ports, and Storage” on page 9-10
- “Work with Events” on page 9-13

Discrete-Event Systems Created with a System Object

In this section...
“Why Use the MATLAB Discrete-Event System Block” on page 9-2
“Discrete-Event System Objects” on page 9-3
“MATLAB Discrete-Event System And System Objects Examples” on page 9-3

Why Use the MATLAB Discrete-Event System Block

System objects let you implement custom event-driven entity-flow systems using the MATLAB language. The MATLAB Discrete-Event System block enables you to use System objects to create this custom block for SimEvents models. You can author such discrete-event systems via a set of MATLAB methods.

You can create a custom discrete-event system that:

- Contains multiple entity storage elements, with each storage element containing multiple SimEvents entities, and configure it to sort entities in a particular order.
- Has an entity or a storage element that can schedule and execute multiple types of events. These events can model activities such as entity creation, consumption, search, transmission (send/receive), and temporal delay.
- Can accept entity/signal as input/output, produce entity and signal as outputs, and support both built-in data types and structured/bus data types.

The MATLAB Discrete-Event System block is similar to the MATLAB System block with the following exceptions:

- The resulting System object™ is an instantiation of the `matlab.DiscreteEventSystem` class rather than the `matlab.System` class.
- The `matlab.DiscreteEventSystem` has its own set of System object methods particular to discrete-event systems. For a complete list, see `matlab.DiscreteEventSystem`. Use these methods to define static properties or define the behavior of objects.
- The `matlab.DiscreteEventSystem` also inherits a subset of the MATLAB System methods. For a complete list of this subset, see `matlab.DiscreteEventSystem`.
- The MATLAB Discrete-Event System block supports only **Interpreted execution** mode. There is no option to select another simulation mode.

Discrete-Event System Objects

Before you use a MATLAB Discrete-Event System block, you must have a discrete-event System object to associate with the block. A System object is a specialized MATLAB class. Discrete-event system objects are designed specifically for implementing and simulating dynamic systems with inputs that change upon discrete instances of events.

For more information on creating discrete-event System objects, see “Implement a Discrete-Event System Object” on page 9-7.

System objects exist in other MATLAB products. MATLAB Discrete-Event System block supports only the System objects written in the MATLAB language.

MATLAB Discrete-Event System And System Objects Examples

For examples of MATLAB Discrete-Event System and System objects, SimEvents Examples in the SimEvents Help browser.

In addition, in the Other category of the SimEvents library, double-click the **Design Patterns** block. The **MATLAB Discrete-Event System** category contains these discrete-event system design patterns:

Example	Application
Custom Generator	Implement a more complicated entity generator.
Custom Server	Implement a more complicated entity server.
Selection Queue	Select a specific entity to output from a queue.

See Also

matlab.DiscreteEventSystem | matlab.System

Related Examples

- “Use a MATLAB Discrete-Event System Block” on page 9-5

More About

- “System Object Integration”

- “Implement a Discrete-Event System Object” on page 9-7
- “Custom Entity Types, Ports, and Storage” on page 9-10
- “Work with Events” on page 9-13

Use a MATLAB Discrete-Event System Block

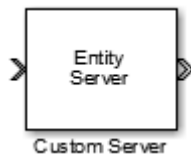
Implement a block and assign a System object to it. You can then explore the block to see the effect.

- 1 Create a model and add the MATLAB Discrete-Event System block from the SimEvents library.



- 2 In the block dialog box, from the **New** list, select **Basic** if you want to create a System object from a template. Modify the template according to your needs and save the System object.
- 3 If the System object already exists, enter its name in the **Discrete-event System object name**. Click the list arrow. If valid System objects exist in the current folder, the names appear in the list.

The MATLAB Discrete-Event System block icon and port labels update to the icons and labels of the corresponding System object. For example, suppose that you selected a System object named `desCustomServer` in your current folder. The block updates as shown in the figure:



See Also

`matlab.DiscreteEventSystem` | `matlab.System`

More About

- “System Object Integration”
- “Discrete-Event Systems Created with a System Object” on page 9-2

- “Implement a Discrete-Event System Object” on page 9-7
- “Custom Entity Types, Ports, and Storage” on page 9-10
- “Work with Events” on page 9-13

Implement a Discrete-Event System Object

The `matlab.DiscreteEventSystem` provides methods that let you work with these elements of a discrete-event system:

- Static properties of the object entity types, ports, and storage
 - `getEntityPortsImpl`
 - `getEntityStorageImpl`
 - `getEntityTypesImpl`
- Event initialization
 - `setupEventsImpl`
- Runtime behavior of the object
 - `blockedImpl`
 - `destroyImpl`
 - `entryImpl`
 - `exitImpl`
 - `generateImpl`
 - `iterateImpl`
 - `timerImpl`

While implementing these methods, define entity type, entity storage, create, schedule, and cancel events. Use these functions:

- Define entity storage
 - `queueFIFO`
 - `queueLIFO`
 - `queuePriority`
- Create and schedule events
 - `eventGenerate`
 - `eventIterate`
 - `eventTimer`

- eventForward
- eventDestroy
- Cancel events
 - cancelGenerate
 - cancelIterate
 - cancelTimer
 - cancelForward
 - cancelDestroy
- Define entity type
 - entityType

See Also

matlab.DiscreteEventSystem | matlab.System |
matlab.DiscreteEventSystem.blockedImpl | matlab.DiscreteEventSystem.cancelDestroy
| matlab.DiscreteEventSystem.cancelForward |
matlab.DiscreteEventSystem.cancelGenerate |
matlab.DiscreteEventSystem.cancelIterate | matlab.DiscreteEventSystem.cancelTimer
| matlab.DiscreteEventSystem.destroyImpl | matlab.DiscreteEventSystem.entityType
| matlab.DiscreteEventSystem.entryImpl | matlab.DiscreteEventSystem.eventDestroy
| matlab.DiscreteEventSystem.eventForward |
matlab.DiscreteEventSystem.eventGenerate |
matlab.DiscreteEventSystem.eventIterate | matlab.DiscreteEventSystem.eventTimer
| matlab.DiscreteEventSystem.exitImpl | matlab.DiscreteEventSystem.generateImpl
| matlab.DiscreteEventSystem.getEntityPortsImpl |
matlab.DiscreteEventSystem.getEntityStorageImpl |
matlab.DiscreteEventSystem.getEntityTypesImpl |
matlab.DiscreteEventSystem.iterateImpl | matlab.DiscreteEventSystem.queueFIFO |
matlab.DiscreteEventSystem.queueLIFO | matlab.DiscreteEventSystem.queuePriority
| matlab.DiscreteEventSystem.queueSysPriority
| matlab.DiscreteEventSystem.setupEventsImpl |
matlab.DiscreteEventSystem.timerImpl

Related Examples

- “Use a MATLAB Discrete-Event System Block” on page 9-5

More About

- “System Object Integration”
- “Discrete-Event Systems Created with a System Object” on page 9-2
- “Custom Entity Types, Ports, and Storage” on page 9-10
- “Work with Events” on page 9-13

Custom Entity Types, Ports, and Storage

In this section...
“Entity Types” on page 9-10
“Custom Entity Ports” on page 9-11
“Custom Entity Storage” on page 9-11

Entity Types

In a discrete-event system, an entity type defines a class of entities that share a common set of data specifications and run-time methods. Examples of data specifications include dimensions, data type, and complexity. Consider these guidelines when defining custom entity types using the `getEntityTypesImpl` method:

- You can specify multiple entity types in one discrete-event system. Each type must have a unique name.
- An entity storage element, input port, and output port must specify the entity type it works with.
- Specify or resolve common data specifications for an entity type. For example, an input port and an output port with the same entity type must have the same data type.
- When forwarding an entity, the data specifications of source and destination must be same in these instances:
 - From input port to storage
 - Between storage elements
 - From a storage element to output port

For a discrete-event system with multiple entity types, each entity type shares a common set of event action methods. When naming these methods, use this convention:

entitytypeActionImpl

For example, if your discrete-event system has two entity types, `car` and `truck`, use method names such as:

```
carEntryImpl  
trucEntryImpl
```


For discrete-event systems with one entity type, you can still use this convention, or just use the convention *actionImpl*, such as

```
entryImpl
```

Custom Entity Ports

A MATLAB discrete-event system supports variable number of input and output ports using the `getNumInputsImpl` and `getNumOutputsImpl` methods. You can also specify which ports are entity ports and the entity types for these ports. Use the `getEntityPortsImpl` method to specify these port properties.

Custom Entity Storage

A MATLAB discrete-event system can contain multiple entity storage elements. Use the `getEntityStorageImpl` method to specify storage elements. An entity storage is a random-access container with these properties:

- Entity type

Entity type this storage is handling.

- Capacity

Maximum number of entities that the storage can contain.

- Storage type

Criteria to sort storage entities (FIFO, LIFO, and priority).

- Key name

Any attribute name used as key name for sorting (such as for priority queues). This property is applicable only when the storage type is `priority`.

- Sorting direction

Sorting order, such as ascending or descending for priority queues. This property is applicable only when the storage type is `priority`.

See Also

`matlab.DiscreteEventSystem` | `matlab.System` |
`matlab.DiscreteEventSystem.getEntityPortsImpl` |

```
matlab.DiscreteEventSystem.getEntityStorageImpl |  
matlab.DiscreteEventSystem.getEntityTypesImpl |  
matlab.DiscreteEventSystem.queueFIFO | matlab.DiscreteEventSystem.queueLIFO  
| matlab.DiscreteEventSystem.queuePriority |  
matlab.DiscreteEventSystem.queueSysPriority
```

Related Examples

- “Use a MATLAB Discrete-Event System Block” on page 9-5

More About

- “System Object Integration”
- “Discrete-Event Systems Created with a System Object” on page 9-2
- “Implement a Discrete-Event System Object” on page 9-7
- “Work with Events” on page 9-13

Work with Events

In this section...

“Event Types” on page 9-13

“Event Actions” on page 9-14

“Initialization Events” on page 9-15

“Cancellation of Previously Scheduled Events” on page 9-15

“Additional Notes” on page 9-15

Event Types

A MATLAB discrete-event system can have the following types of events:

- Storage events — Schedule these events on a storage element. The actor is a storage element.
 - Generate
Create a new entity inside a storage element.
 - Iterate
Iterate and process each entity of a storage element.
- Entity events — Schedule these events on an entity. Actor is an entity.
 - Timer
Delay an entity.
 - Forward
Move an entity from its current storage to another storage or output port.
 - Destroy
Destroy the existing entity of a storage element.

You can:

- Schedule events

- Define event actions in response to events
- Initialize events
- Cancel events

Event Actions

When an event occurs, a discrete-event system responds to it by invoking a corresponding action. Implement these actions as System object methods. This table lists each action method and the triggering event.

Action	Triggering Event	Description
<code>generateImpl</code>	Generate	Called after a new entity is created inside a storage element.
<code>iterateImpl</code>	Iterate	Upon execution of an iterate event, the discrete-event system calls this method for each entity, starting from the front of the storage, to the back. You can stop the iteration before reaching the last entity. If the entity order must change, the order changes after the entire iteration completes.
<code>timerImpl</code>	Timer	Called when a timer of an entity expires (completes).
<code>entryImpl</code>	Forward	When an entity is forwarded from storage <i>A</i> to storage <i>B</i> , the discrete-event system first calls <code>exitImpl</code> of <i>A</i> , then <code>entryImpl</code> of <i>B</i> .
<code>exitImpl</code>	Forward	When an entity is forwarded from storage <i>A</i> to storage <i>B</i> , the discrete-event system first calls <code>exitImpl</code> of <i>A</i> , then <code>entryImpl</code> of <i>B</i> .
<code>blockedImpl</code>	Forward	Upon execution of a forward event, if entity cannot leave due to blocking, the discrete-event system calls the <code>blockedImpl</code> action method.
<code>destroyImpl</code>	Destroy	The discrete-event system calls this method before an existing entity is destroyed and removed from storage.

Initialization Events

Use the `setupEventsImpl` method to schedule initial events of a discrete-event system. You can schedule only storage events using this method. This method does not have a specific entity type name.

Cancellation of Previously Scheduled Events

Use the `cancel*` methods to cancel previously scheduled events of a discrete-event system.

Additional Notes

- Forward events

If a forward event fails because of blocking, the forward event remains active. When space becomes available, the discrete-event system reschedules the forward event for immediate execution

- Tagging events

You can schedule multiple events of the same type for the same actor. When using multiple events of the same type, use tags to distinguish between the events. For example, an entity can have multiple timers with distinct tags. When one timer expires, you can use the `tag` argument of the `timerImpl` method to differentiate which timer it is.

If you schedule two events with the same tag on the same actor, the later event replaces the first event. If you schedule two events with different tags, the discrete-event system calls them separately.

See Also

`matlab.DiscreteEventSystem` | `matlab.System` |
`matlab.DiscreteEventSystem.blockedImpl` | `matlab.DiscreteEventSystem.cancelDestroy`
| `matlab.DiscreteEventSystem.cancelForward`
| `matlab.DiscreteEventSystem.cancelGenerate`
| `matlab.DiscreteEventSystem.cancelIterate` |
`matlab.DiscreteEventSystem.cancelTimer` | `matlab.DiscreteEventSystem.destroyImpl`
| `matlab.DiscreteEventSystem.entryImpl` | `matlab.DiscreteEventSystem.eventDestroy`
| `matlab.DiscreteEventSystem.eventForward` |

`matlab.DiscreteEventSystem.eventGenerate` | `matlab.DiscreteEventSystem.eventIterate`
| `matlab.DiscreteEventSystem.eventTimer` | `matlab.DiscreteEventSystem.exitImpl` |
`matlab.DiscreteEventSystem.generateImpl` | `matlab.DiscreteEventSystem.iterateImpl`
| `matlab.DiscreteEventSystem.setupEventsImpl` |
`matlab.DiscreteEventSystem.timerImpl`

Related Examples

- “Use a MATLAB Discrete-Event System Block” on page 9-5

More About

- “System Object Integration”
- “Discrete-Event Systems Created with a System Object” on page 9-2
- “Implement a Discrete-Event System Object” on page 9-7
- “Custom Entity Types, Ports, and Storage” on page 9-10

Custom Visualization

- “Interface for Custom Visualization” on page 10-2
- “Create an Application” on page 10-4
- “Use the Observer to Monitor the Model” on page 10-7
- “Stop Simulation and Disconnect the Model” on page 10-8
- “Custom Visualization Examples” on page 10-9

Interface for Custom Visualization

In this section...
“SimulationObserver Class” on page 10-2
“Custom Visualization Workflow” on page 10-2

SimulationObserver Class

To create an observer, create a class that derives from the `simevents.SimulationObserver` object. You can use observers to implement animators to visualize model simulation, or debuggers.

- To help understand queue impact, visualize entities moving through the model during simulation,
- Develop presentation tools showing model simulation via an application-oriented interface, such as restaurant queue activity.
- Debug and examine entity activity.
- Examine queue contents.

The `simevents.SimulationObserver` object provides methods that let you:

- Create observer or animation objects.
- Identify model blocks for notification of run-time events.
- Interact with the event calendar.
- Perform activities when a model pauses, continues after pausing, and terminates.

SimEvents models call these functions during model simulation.

Custom Visualization Workflow

- 1 Create an application file.
 - a Define a class that inherits from the `simevents.SimulationObserver` class.
 - b Create an observer object that derives from this class.
 - c From the `simevents.SimulationObserver` methods, implement the functions you want for your application. This application comprises your observer.

- 2 Open the model.
- 3 Create an instance of your class.
- 4 Run the model.

See Also

`simevents.SimulationObserver`

Related Examples

- “Create an Application” on page 10-4
- “Use the Observer to Monitor the Model” on page 10-7
- “Stop Simulation and Disconnect the Model” on page 10-8
- “Custom Visualization Examples” on page 10-9

Create an Application

You can use these methods in your derived class implementation of `simevents.SimulationObserver`.

Action	Method
Specify behavior when simulation starts.	<code>simStarted</code>
Specify behavior when simulation pauses.	<code>simPaused</code>
Specify behavior when simulation resumes.	<code>simResumed</code>
Define observer behavior when simulation is terminating.	<code>simTerminating</code>
Specify list of blocks to be notified of entity entry and exit events.	<code>getBlocksToNotify</code>
Specify whether you want notification for all events in the event calendar.	<code>notifyEventCalendarEvents</code>
Specify behavior after an entity enters a block that has entity storage.	<code>postEntry</code>
Specify behavior before an entity exits a block with entity storage.	<code>preExit</code>
Specify behavior before execution of an event.	<code>preExecute</code>
Add block to list of blocks to be notified.	<code>addBlockNotification</code>
Remove block from list of blocks being notified.	<code>removeBlockNotification</code>
Get handles to event calendars.	<code>getEventCalendars</code>
Get list of blocks that store entities.	<code>getAllBlockWithStorages</code>

Action	Method
Return block handle for a given block path.	<code>getHandleToBlock</code>
Return storage handles of specified block.	<code>getHandlesToBlockStorages</code>

- 1 In the MATLAB Command Window, select **New > Class**.
- 2 In the first line of the file, inherit from the `simevents.SimulationObserver` class. For example:

```
classdef seExampleRestaurantAnimator < simevents.SimulationObserver
    seExampleRestaurantAnimator is the name of the new observer object.
```

- 3 In the **properties** section, enter the properties for your application.
- 4 In the **methods** section, implement the functions for your application.
- 5 To construct the observer object, enter a line like the following in the **methods** section of the file:

```
function this = seExampleRestaurantAnimator
    % Constructor
    modelName = 'seExampleCustomVisualization';
    this@simevents.SimulationObserver(modelName);
    this.mModel = modelName;
end
```

The `matlabroot\toolbox\simevents\examples` folder contains this application example, `seExampleRestaurantAnimator.m`. This example uses an observer object to implement an animator for the `seExampleCustomVisualization` model.

For more information, see **Using Custom Visualization for Entities** in the **SimEvents Examples** tab.

See Also

`simevents.SimulationObserver`

Related Examples

- “Use the Observer to Monitor the Model” on page 10-7
- “Stop Simulation and Disconnect the Model” on page 10-8

- “Custom Visualization Examples” on page 10-9

More About

- “Interface for Custom Visualization” on page 10-2

Use the Observer to Monitor the Model

- 1 Open the model to observe.
- 2 At the MATLAB command prompt, to enable the animator for the model:

```
>> obj=seExampleRestaurantAnimator;
```
- 3 Simulate the model.

When the model starts, the animator is displayed in a figure window. As the model runs, it makes calls into your application to see if you have implemented one of the predefined set of functions.

Note: As a result of the instrumentation to visualize the simulation, the simulation is slower than without the instrumentation.

See Also

simevents.SimulationObserver

Related Examples

- “Create an Application” on page 10-4
- “Stop Simulation and Disconnect the Model” on page 10-8
- “Custom Visualization Examples” on page 10-9

More About

- “Interface for Custom Visualization” on page 10-2

Stop Simulation and Disconnect the Model

- 1 Stop the simulation.
- 2 At the MATLAB command prompt, clear the animator from the model. For example:

```
clear obj;
```

See Also

simevents.SimulationObserver

Related Examples

- “Create an Application” on page 10-4
- “Use the Observer to Monitor the Model” on page 10-7
- “Custom Visualization Examples” on page 10-9

More About

- “Interface for Custom Visualization” on page 10-2

Custom Visualization Examples

In this section...
“Structure of Example Model” on page 10-9
“Visualize Entities” on page 10-9

The `Using Custom Visualization for Entities` example visualizes a restaurant layout with customer entities entering, dining, and leaving. It uses `seExampleCustomVisualization` to model a restaurant. To observe the visualization, start the model and the animator.

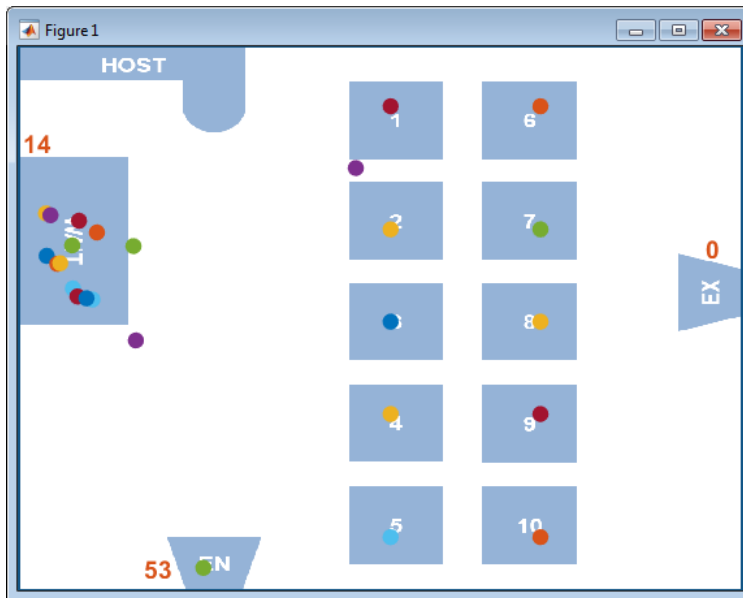
Structure of Example Model

The `seExampleCustomVisualization` model has these major components:

- The `Entity Generator` block (`Patron Enter`) generates entities representing customer entities. Each customer has a *TimeToDine* amount of time to dine.
- These customer entities enter a waiting area, where a `Resource Acquirer` block acquires a table for the customer.
- The `Resource Pool` block contains 10 table resources.
- When a table entity is available for a waiting customer entity, the `Entity Server` block serves the customer for a *TimeToDine* amount of time.
- When a customer entity is done dining, the `Resource Releaser` block releases the table resource back to the resource pool.
- The customer entity leaves the restaurant through the `Entity Terminator` block (`Patron Leave`).

Visualize Entities

The `seExampleRestaurantAnimator` application animates the diners entering, dining, and leaving the restaurant. The animator application draws a different colored dot for each customer. As customers move through the restaurant, the application animates the motion of the dots.



See Also

`simevents.SimulationObserver`

Related Examples

- “Create an Application” on page 10-4
- “Use the Observer to Monitor the Model” on page 10-7
- “Stop Simulation and Disconnect the Model” on page 10-8

More About

- “Interface for Custom Visualization” on page 10-2