SAS® Event Stream Processing 4.2: Publish/Subscribe API

Overview to the Publish/Subscribe APIs

SAS Event Stream Processing provides publish/subscribe application programming interfaces (APIs) for C, Java, and Python. Use these APIs to do the following:

- publish event streams into a running event stream processor project source window
- subscribe to a project's window event stream, either from the same machine or from another machine on the network

The APIs support TCP/IP networking. Thus, publish and subscribe applications can run on any machine with network access to an event stream processing engine, or on the engine platform itself. APIs are available on all architectures supported by SAS Event Stream Processing.

The publish/subscribe APIs handle cross-platform usage. For example, you can subscribe using the Java API to event streams in an engine that runs on Linux even though the byte order Endianness is different.

You can also subscribe to an event stream so that it can be continuously loaded into a database for persistence. In this case, you more likely would use an event stream processor database connector or adapter.

Connectors are in-process classes that publish or subscribe to and from event stream processing windows. Adapters are stand-alone executable files that publish and subscribe, potentially over a network.

Note: The APIs provide cross-platform connectivity and Endianness compatibility between the application and other networked applications, clients, and data feeds. The APIs are IPv4 compliant.

Using the C Publish/Subscribe API

The C Publish/Subscribe API from the Engine's Perspective

To enable publish/subscribe for the engine instance using the C++ Modeling API, you must provide a port number to the `pubsub_ENABLE()` parameter in the `dfESPengine::initialize()` call as follows:

```
dfESPengine *engine;
engine = dfESPengine::initialize(argc, argv, "engine",
pubsub_ENABLE(33335));

if (engine == NULL) {
     cerr <<"Error: dfESPengine::initialize() failed\n";
     return 1;
}
```

Note: The XML server equivalent is to specify "–`pubsub` *`port`*" on the command line, or specify the port using the port attribute in the engine element.

Clients can use the port number (in this example 33335) to establish publish/subscribe connections. If publish/subscribe is not required, then use `pubsub_DISABLE` for that parameter.

If publish/subscribe is required and clients must be authenticated, use one of the following:

- `pubsub_ENABLE_OAUTH(port, clientId)`, where *clientId* is a CF UAA OAuth server client ID
- `pubsub_ENABLE_SASLOGONOAUTH(port, sasLogonURL)`, where *sasLogonURL* is the base services URL for a SASLogon service

For the XML server, specify **`-auth clientId`** or **`-saslogon-url`** on the command line.

For more information, see "Enabling Authentication on Socket Connections" in *SAS Event Stream Processing: Security*.

To initialize publish/subscribe capabilities for a project, `project->setPubSub()` is called before calling `engine->startProjects()`.

For example:

```
project->setPubSub(dfESPproject::ps_AUTO);
engine->startProjects();
```

Note: The XML server equivalent is to specify the publish/subscribe capabilities using the **`pubsub`** attribute in the **`project`** element.

This code opens a server listener socket on port 33335 to enable client subscribers and publishers to connect to the engine application or server for publish/subscribe services. After the connection request is made for publish/subscribe by a client (as described below), an ephemeral port is returned, which the publish/subscribe API uses for this connection.

In cases when you need to override ephemeral ports for a specific port (for security purposes), specify `project->setPubSub` with a second parameter that is the preferred port to be used for the actual connections to this project.

For example:

```
project->setPubSub(dfESPproject::ps_AUTO, 33444);
```

Note: The XML server equivalent is to specify the port using the **`port`** attribute in the **`project`** element.

The first parameter of `project->setPubSub()` applies only to subscription services and it specifies how windows in the project are enabled to support client subscriptions. Specifying `ps_AUTO` enables clients to subscribe to all window output event streams in the project.

Alternatively, you can enable windows manually by specifying `ps_MANUAL`. For non-trivial projects, enable the specific windows of interest manually because automatically enabling all windows has a noticeable impact on overall performance. You can also specify `ps_NONE`, which disables subscribing for all windows.

If you use `ps_MANUAL` in `project->setPubSub()` to specify manual enabling of window subscribes, then use `enableWindowSubs()` for each desired window to enable the subscribe as follows:

```
project->enableWindowSubs(dfESPwindow *w);
```

Note: The XML server equivalent is to enable or disable pubsub using the **`pubsub`** attribute in the **`window`** element.

If, however, you specified `ps_AUTO` or `ps_NONE` in `setPubSub()`, then subsequent calls to `enableWindowSubs()` are ignored and generate a warning.

Note: Clients can publish an event stream into any source window (and only source windows) in a project that is currently running. All source windows are enabled for publishing by default.

The C Publish/Subscribe API from the Client's Perspective

Clients that subscribe from or publish to an engine's event streams using the C publish/subscribe API need to first initialize services on the client (using `C_dfESPpubsubInit()`). Next, they need to start a subscription using `C_dfESPsubscriberStart()` and publisher using `C_dfESPpublisherStart()`, and then connect to the application or server using `C_dfESPpubsubConnect()`.

Clients that implement a publisher can then call `C_dfESPpublisherInject()` as needed to publish event blocks into the source window specified in the URL passed to `C_dfESPpublisherStart()`.

The specifics of the client publish/subscribe API are as follows.

- Your client application must include the header file C_dfESPpubsubApi.h to provide publisher and subscriber services. In addition to the API calls, this file also defines the signatures of the user-supplied callback functions, of which there are currently two: the subscribed event block handler and the publish/subscribe failure handler.
- The subscribed event block handler is used only by subscriber clients. It is called when a new event block from the application or server arrives. After processing the event block, the client is responsible for freeing it by calling `C_dfESPeventblock_destroy()`. The signature of this user-defined callback is as follows, where "`eb`" is the event block just read, "`schema`" is the schema of the event for client processing, and `ctx` is an optional context object containing call state:

  ```
  typedef void (*C_dfESPsubscriberCB_func)(C_dfESPeventblock eb,
      C_dfESPschema schema, void *ctx);
  ```

- The second callback function, `C_dfESPpubsubErrorCB_func()`, is optional for both subscriber and publisher clients. If supplied (that is, no NULL), it is called for every occurrence of an abnormal event within the client services, such as an unsolicited disconnect. This enables the client to handle and possibly recover from publish/subscribe services errors. The signature for this callback function is below, where the following is true:
  - `failure` is either `pubsubFail_APIFAIL`, `pubsubFail_THREADFAIL`, or `pubsubFail_SERVERDISCONNECT`
  - `code` provides the specific code of the failure
  - `ctx` is an optional context object containing call state

  ```
  typedef void (*C_dfESPpubsubErrorCB_func)(C_dfESPpubsubFailures
  ```

```
failure, C_dfESPpubsubFailureCodes code);
```

- The `C_dfESPpubsubFailures` and `C_dfESPpubsubFailureCodes` enums are defined in `C_dfESPpubsubFailures.h`.
- A publisher client uses the `C_dfESPpublisherInject()` API function to publish event blocks into a source window in the application or server. The event block is injected into the source window running in the continuous query and project specified in the URL passed to `C_dfESPpublisherStart()`. A client can publish events to multiple windows in a project by calling `C_dfESPpublisherStart()` once for each window and then passing the appropriate client object to `C_dfESPpublisherInject()` as needed.
- A client can query the application or server at any time to discover currently running windows, continuous queries, and projects in various granularities. This information is returned to the client in the form of a list of strings that represent names, which might subsequently be used to build URL strings to pass to `C_dfESPsubscriberStart()` or `C_dfESPpublisherStart()`. See the function description for a list of supported queries.

Functions for the C Publish/Subscribe API

The functions provided for client publish/subscribe in the publish/subscribe API are as follows. You can use them for simple connections or for more robust and complex connections with multiple connections or recovery handling by the client.

int C_dfESPpubsubInit(C_dfESPLoggingLevel *level*, const char **logConfigPath*)

Parameters:

`level`
the logging level

`logConfigPath`
the full pathname to the log configuration file

Return values:

1
success

0
failure — an error is written to the log

Note: This function initializes client publisher and subscriber services, and must be called (only once) before making any other client calls, with the exception of `C_dfESPpubsubSetPubsubLib()`.

clientObjPtr C_dfESPpublisherStart(char **serverURL*, C_dfESPpubsubErrorCB_func *errorCallbackFunction*, void **ctx*)

Parameters:

`serverURL`
string representing the destination host, port, project, continuous query, and window

`serverURL` format
"`dfESP://host:port/project/contquery/window`"

`errorCallbackFunction`
either NULL or a user-defined function pointer for handling client service failures

`ctx`
optional context pointer for passing state into this call

Return value:

a pointer to a client object that is passed to all API functions described below or NULL if there was a failure (error written to the log).

clientObjPtr C_dfESPpublisherStart(char *_serverURL_, C_dfESPpubsubErrorCB_func _errorCallbackFunction_, void *_ctx_)

Note: This function validates and retains the connection parameters for a specific publisher client connection.

clientObjPtr C_dfESPGDpublisherStart()

Parameters: Same parameters and return value as `C_dfESPpublisherStart()`. Additional required parameter: a Guaranteed Delivery callback function pointer of type `C_dfESPGDpublisherCB_func`. Additional required parameter: filename of this publisher's guaranteed delivery configuration file.

clientObjPtr C_dfESPsubscriberStart(char *_serverURL_, C_dfESPsubscriberCB_func _callbackFunction_, C_dfESPpubsubErrorCB_ func _errorCallbackFunction_, void *_ctx_)

Parameters:

`serverURL`
string representing the destination host, port, project, continuous query, and window in the engine. Also specifies the client snapshot requirement - if "true" the client receives the current snapshot state of the window prior to any incremental updates.

Specifying the client collapse requirement is optional. By default, it is false. When true, UPDATE_BLOCK events are converted to UPDATE events in order to make subscriber output publishable.

`serverURL` format
"`dfESP://`*`host`*`:`*`port`*`/`*`project`*`/`*`contquery`*`/`*`window`*`?snapshot=true | false <?collapse=true | false><?rmretdel=true | false>`"

`callbackFunction`
a pointer to a user-defined function for handling received event blocks. This function must call `C_dfESPeventblock_destroy()` to free the event block.

`errorCallbackFunction`
either NULL or a user-defined function pointer for handling subscription service failures

`ctx`
optional context pointer for parsing state into this call

Return value: a pointer to a client object that is passed to all API functions described below, or NULL if there was a failure (error written to the log).

Note: This function validates and retains the connection parameters for a specific subscriber client connection.

clientObjPtr C_dfESPGDsubscriberStart()

Parameters: Same parameters and return value as `C_dfESPsubscriberStart()`. Additional required parameter: filename of this subscriber's guaranteed delivery configuration file.

int C_dfESPpubsubConnect(clientObjPtr *client*)

Parameter:

client
pointer to a client object returned by `C_dfESPsubscriberStart()` or `C_dfESPpublisherStart()` or `C_dfESPGDsubscriberStart()` or `C_dfESPGDpublisherStart()`

Return values:

1
success

0
failure — error written to the log

Note: This function attempts to establish a connection with the application or server.

int C_dfESPpubsubDisconnect(clientObjPtr *client*, int *block*)

Parameters:

client
pointer to a client object returned by `C_dfESPsubscriberStart()` or `C_dfESPpublisherStart()` or `C_dfESPGDsubscriberStart()` or `C_dfESPGDpublisherStart()`

block
set to 1 to wait for all queued events to be processed, else 0

Return values:

1
success

0
failure — error written to the log

Note: This function closes the connection associated with the passed client object.

int C_dfESPpubsubStop(clientObjPtr *client*, int *block*)

Parameters:

client
pointer to a client object returned by `C_dfESPsubscriberStart()` or `C_dfESPpublisherStart()` or `C_dfESPGDsubscriberStart()` or `C_dfESPGDpublisherStart()`

block
set to 1 to wait for all queued events to be processed, else 0

Return values:

1
success

0
failure — error written to the log

Note: This function stops the client session and removes the passed client object.

int C_dfESPpublisherInject(clientObjPtr *client*, C_dfESPeventblock *eventBlock*)

Parameters:

client
pointer to a client object returned by `C_dfESPpublisherStart()` or `C_dfESPGDsubscriberStart()`

eventBlock
the event block to inject into the engine. The block is injected into the source window, continuous query, and project associated with the passed client object.

Return values:

1
success

0
failure — error written to the log

Note: This function implements the client publisher function by publishing events into the engine. Event blocks can be built using other additional functions provided in the event stream processor objects C API.

C_dfESPstringV C_dfESPpubsubQueryMeta(char **queryURL*)

Parameter:

queryURL
string representing the query to be posted to the engine.

Return value: a vector of strings representing the list of names comprising the response to the query, or NULL if there was a failure (error written to the log). The end of the list is denoted by an empty string. The caller is responsible for freeing the vector by calling `C_dfESPstringV_free()`.

Note: This function implements a general event stream processor metadata query mechanism. This mechanism enables a client to discover projects, continuous queries, windows, window schema, and window edges currently running in the engine. This mechanism has no dependencies or interaction with any other activity performed by the client. The function opens an independent socket to send the query and closes the socket upon receiving the query reply.

Supported formats of *queryURL*

`"dfESP://host:port?get=projects"`	returns names of currently running projects
`"dfESP://host:port?get=projects_pubsubonly"`	returns names of currently running projects with publish/subscribe enabled
`"dfESP://host:port?get=queries"`	returns names of continuous queries in currently running projects
`"dfESP://host:port/project?get=windows_sourceonly"`	returns names of source windows in the specified project, if the project is running
`"dfESP://host:port/project?get=windows_derivedonly"`	returns names of derived windows in the specified project, if the project is running

Supported formats of *queryURL*	
"dfESP://*host*:*port*?get=queries_pubsubonly"	returns names of continuous queries containing publish/subscribe enabled windows in currently running projects
"dfESP://*host*:*port*?get=windows"	returns names of windows in currently running projects
"dfESP://*host*:*port*?get=windows_pubsubonly"	returns names of publish/subscribe enabled windows in currently running projects
"dfESP://*host*:*port*?get=windowsandtypes"	returns names of windows in currently running projects; each returned window name is followed by a colon and the window type
"dfESP://*host*:*port*/*project*/*contquery*?get=windows_sourceonly"	returns names of source windows in the specified continuous query and project, if the project is running
"dfESP://*host*:*port*/*project*/*contquery*?get=windows_derivedonly"	returns names of derived windows in the specified continuous query and project, if the project is running
"dfESP://*host*:*port*/*project*?get=windows"	returns names of windows in the specified project, if running
"dfESP://*host*:*port*/*project*?get=windowsandtypes"	returns names of windows in the specified project, if running. Each returned window name is followed by a colon and the window type
"dfESP://*host*:*port*/*project*?get=windows_pubsubonly"	returns names of publish/subscribe-enabled windows in the specified project, if running
"dfESP://*host*:*port*/*project*?get=queries"	returns names of continuous queries in the specified project, if running

Supported formats of *queryURL*	
"dfESP://*host*:*port*/*project*?get=queries_pubsubonly"	returns names of continuous queries containing publish/subscribe-enabled windows in the specified project, if running
"dfESP://*host*:*port*/*project*/*contquery*?get=windows"	returns names of windows in the specified continuous query and project, if running
"dfESP://*host*:*port*/*project*/*contquery*?get=windowsandtypes"	returns names of windows in the specified continuous query and project, if running. Each returned window name is followed by a colon and the window type.
"dfESP://*host*:*port*/*project*/*contquery*?get=windows_pubsubonly"	returns names of publish/subscribe-enabled windows in the specified continuous query and project, if running
"dfESP://*host*:*port*/*project*/*contquery*/*window*?get=schema"	returns a single string that is the serialized version of the window schema
"dfESP://*host*:*port*/*project*/*contquery*/*window*?get=edges"	returns the names of all the window's edges
"dfESP://*host*:*port*/*project*/*contquery*/*window*?get=rowcount"	returns the number of rows currently in the window

C_dfESPstringV C_dfESPpubsubGetModel(char **queryURL*)

Parameter:

queryURL
string representing the query to be posted to engine.

Supported formats of *queryURL* are as follows:

- "dfESP://*host*:*port*" – returns names of all windows in the model and their edges
- "dfESP://*host*:*port*/*project*" – returns names of all windows in the project and their edges
- "dfESP://*host*:*port*/*project*/*contquery*" – returns names of all windows in the continuous query and their edges

Return value:

A vector of strings representing the response to the query, or NULL if there was a failure (error written to the log). The format of each string is "*project*/*query*/*window*: *edge1*, *edge2*, ...". The end of the list is denoted by an empty string. The caller is responsible for freeing the vector by calling `C_dfESPstringV_free()`.

C_dfESPstringV C_dfESPpubsubGetModel(char *_queryURL_)

Note: This function allows a client to discover an engine by returning the complete set of windows in the model or project or continuous query, along with the window's edges. It has no dependencies or interaction with any other activity performed by the client. It opens an independent socket to send the query and closes the socket upon receiving the query reply.

void C_dfESPpubsubShutdown()

Shutdown publish/subscribe services

int C_dfESPpubsubPersistModel(char *_hostportURL_, const char *_persistPath_)

Parameters:

hostportURL
string in the form "`dfESP://host:port`"

persistpath
the absolute or relative pathname for the persist file on the target platform

Return values:

1
success

0
failure — error written to the log

Note: This function instructs the engine at the *hostportURL* to persist its current state to disk. It has no dependencies or interaction with any other activity performed by the client. It opens an independent socket to send the request and closes the socket upon receiving the request return code.

int C_dfESPpubsubQuiesceProject(char *_projectURL_, clientObjPtr _client_)

Parameters:

projectURL
string in the form **`"dfESP://host:port/project"`**

client
optional pointer to a client object returned by `C_dfESPsubscriberStart()` or `C_dfESPpublisherStart()` or `C_dfESPGDsubscriberStart()` or `C_dfESPGDpublisherStart()`. If not null, wait for the specified client's queued events to be processed before quiescing the project.

Return values:

1
success

0
failure — error written to the log.

Note: This function instructs the engine at the *projectURL* to quiesce the project in *projectURL*. This call is synchronous, meaning that when it returns the project has been quiesced.

int C_dfESPsubscriberMaxQueueSize(char ****serverURL*, int *maxSize*, int *block*)**

Parameters:

serverURL
String for the server URL in one of the following forms:

- **"dfESP://*host*:*port*"**
- **"dfESP://*host*:*port*/*project*"**
- **"dfESP://*host*:*port*/*project*/*contquery*"**
- **"dfESP://*host*:*port*/*project*/*contquery*/*window*"**

maxsize
the maximum number of event blocks that can be queued for any single subscriber to a window in the *serverURL*

block
set to 1 to wait for queue size to fall below *maxSize*, else disconnect the client

Return values:

1
success

0
failure - error written to the log

Note: Use this function to configure the maximum size of all queues used to enqueue event blocks sent to subscribers in a project, query, or window. Use it to limit the amount of memory consumed by these queues. The block parameter specifies the behavior when the maximum is hit.

int C_dfESPpubsubSetPubsubLib(C_dfESPpsLib *psLib*)

Parameters:

psLib
Number representing the client/server transport

Supported values of *psLib* are as follows:

- ESP_PSLIB_NATIVE (default)
- ESP_PSLIB_SOLACE — In this mode a client configuration file named solace.cfg must be present in the current directory to provide appliance connectivity parameters.
- ESP_PSLIB_TERVELA — In this mode, a client configuration file named **client.config** must be present in the current directory to provide appliance connectivity parameters.
- ESP_PSLIB_RABBITMQ — In this mode, a client configuration file named **rabbitmq.cfg** must be present in the current directory to provide Rabbit MQ server connectivity parameters.
- ESP_PSLIB_KAFKA — In this mode, a client configuration file named **kafka.cfg** must be present in the current directory to provide Kafka cluster connectivity parameters.

int C_dfESPpubsubSetPubsubLib(C_dfESPpsLib *psLib*)

Solace configuration file format:

```
solace
{
SESSION_HOST = "10.37.150.244:55555"
SESSION_USERNAME = "pub1"
SESSION_PASSWORD = "pub1"
SESSION_VPN_NAME = "SAS"
SESSION_RECONNECT_RETRIES = "3"
SESSION_REAPPLY_SUBSCRIPTIONS = true
SESSION_TOPIC_DISPATCH = true
}
sas
{
buspersistence = false
queuename = "myqueue"
protobuf = false
protofile = "./GpbHistSimFactory.proto"
protomsg = "GbpTrade"
json = false
dateformat = "%Y-%m-%d %H:%M:%S"
passwordencrypted = false
}
```

Note: If `passwordencrypted = true`, the value in **`SESSION_PASSWORD`** must be the encrypted password generated by this OpenSSL command: `echo "`*`SESSION_PASSWORD`*`" | openssl enc -e -aes-128-cbc -a -salt -pass pass:"SASespSOLclientUsedByUser=`*`SESSION_USERNAME`*`"`

Tervela configuration file format:

```
USERNAME            esp
PASSWORD            esp
PRIMARY_TMX         10.37.8.175
LOGIN_TIMEOUT       45000
GD_CONTEXT_NAME     tvaIF
GD_MAX_OUT          10000
PASSWORDENCRYPTED       0
```

Note: If `PASSWORDENCRYPTED = 1`, the value in **`PASSWORD`** must be the encrypted password generated by this OpenSSL command: `echo "`*`PASSWORD`*`" | openssl enc -e -aes-128-cbc -a -salt -pass pass:"SASespTVAclientUsedByUser=`*`USERNAME`*`"`

int C_dfESPpubsubSetPubsubLib(C_dfESPpsLib *psLib*)

RabbitMQ configuration file format:

```
rabbitmq
{
host = "my.machine.com"
port = "5672"
exchange = "SAS"
userid = "guest"
password = "guest"
}

sas
{
buspersistence = false
queuename = "subpersist"
protobuf = false
protofile = "./GpbHistSimFactory.proto"
protomsg = "GpbTrade"
json = false
noreplay = false
noautoack = false
dateformat = "%Y-%m-%d %H:%M:%S"
passwordencrypted = false
}
```

Note: If `passwordencrypted = true`, the value in `password` must be the encrypted password generated by this OpenSSL command: `echo "`*`password`*`" | openssl enc -e -aes-128-cbc -a -salt -pass pass:"SASespRMQclientUsedByUser=`*`userid`*`"`

Note: The `buspersistence` and `queuename` parameters mean different things for subscribers or publishers of Rabbit MQ messages. For a publisher, `queuename` is always ignored. `If buspersistence = false`, messages are sent in non-persistent delivery mode. Otherwise, delivery mode is persistent. For a subscriber, `queuename` is always used when creating the receive queue. If `buspersistence = false`, all queues and exchanges created by the client are non-durable and auto-delete. If `buspersistence = true`, all exchanges and queues are durable and not auto-delete. The `noreplay` parameter is false by default. When set to true, messages received from Rabbit MQ are acknowledged even when `buspersistence` is enabled. By default, the `noautoack` parameter is set to **`false`**. When set to **`true`**, messages received from Rabbit MQ are explicitly acknowledged instead of implicitly acknowledged through the Rabbit MQ `autoack`. This means that any errors detected in received message processing suppress the `ack` and leave the message on the Rabbit MQ queue.

int C_dfESPpubsubSetPubsubLib(C_dfESPpsLib *psLib*)

Kafka configuration file format:

```
kafka
{
hostport = "kafkahost:9092"
partition = "0"
initialoffset = "largest"
groupid = "mygroup"
}

sas
{
protobuf = false
protofile = "./GpbHistSimFactory.proto"
protomsg = "GpbTrade"
json = false
dateformat = "%Y-%m-%d %H:%M:%S"
}
```

Return values:

1
: success

0
: failure

Note: This function call is optional, but if called it must be called before calling `C_dfESPpubsubInit()`. It modifies the transport used between the client and the engine from the default peer-to-peer TCP/IP based socket connection that uses the ESP publish/subscribe protocol. Instead, you can specify ESP_PSLIB_SOLACE, ESP_PSLIB_TERVELA, ESP_PSLIB_RABBITMQ, or ESP_PSLIB_KAFKA to indicate that the client's TCP/IP peer is a Solace appliance, a Tervela appliance, a Rabbit MQ server, or a Kafka cluster. This mode requires that the engine runs a Solace, Tervela, Rabbit MQ, or Kafka connector to provide the corresponding inverse client to the appliance. The topic names used by the appliance are coordinated by the publish/subscribe client and connector to correctly route event blocks through the appliance.

Note: When using the Solace, Tervela, Rabbit MQ, or Kafka transports, the following publish/subscribe API functions are not supported:

```
C_dfESPpubsubGetModel()
C_dfESPGDpublisherStart()
C_dfESPGDpublisherGetID()
C_dfESPGDsubscriberStart()
C_dfESPGDsubscriberAck()
C_dfESPpubsubSetBufferSize()
C_dfESPsubscriberMaxQueueSize()
C_dfESPpubsubPingHostPort()
```

C_dfESPGDsubscriberAck(clientObjPtr *client*, CdfESPeventblock *eventblock*)

Parameters:

- *client* pointer to a client object returned by `C_dfESPGDsubscriberStart()`
- *eventBlock* pointer to the event block being acknowledged back to the publisher. The event block must not be freed before this function returns.

Return values:

- 1 = success
- 0 = failure

C_dfESPGDpublisherCB_func()

Parameters: Signature of the guaranteed delivery publisher callback function passed to `C_dfESPGDpublisherStart()`. This function is invoked by the API to return the guaranteed delivery status of a published event block back to the publisher.

- Parameter 1: READY or ACK or NACK (acknowledged or not acknowledged).
- Parameter 2: 64-bit event block ID
- Parameter 3: the user context pointer passed to `C_dfESPGDpublisherStart()`

Return value: Void

C_dfESPGDpublisherGetID()

Return value: 64-bit event block ID. Might be called by a publisher to obtain sequentially unique IDs to be written to event blocks before injecting them to a guaranteed delivery-enabled publish client.

int C_dfESPpubsubSetBufferSize(clientObjPtr *client*, int32_t *mbytes*)

Parameters:

`client`
pointer to a client object returned by `C_dfESPsubscriberStart()` ,`C_dfESPpublisherStart()` , `C_dfESPGDsubscriberStart()`, or `C_dfESPGDpublisherStart()`

`mbytes`
the read and write buffer size, in units of 1MB

Return values:

1
success

0
failure

Note: This function call is optional, but if called it must be called after `C_dfESPsubscriberStart()`, `C_dfESPpublisherStart()`, `C_dfESPGDsubscriberStart()`, or `C_dfESPGDpublisherStart()` and before `C_dfESPpubsubConnect()`. It modifies the size of the buffers used for socket Read and Write operations. By default this size is 16MB

int C_dfESPpubsubPingHostPort(char **serverURL*)

Parameters:

`serverURL`
A string with the format **`"dfESP://host:port"`**

Return values:

1
port is open and it is a publish/subscribe port

0
port is not open or is not a publish/subscribe port

Note: This function pings a running engine to determine whether the specified port is open. It also exchanges and verifies a magic number in order to confirm that the open port is a publish/subscribe port.

int C_dfESPpubsubSetTokenLocation(char *_tokenLocation_)

Parameters:

tokenLocation
full path and filename of the file that contains the token

Return values:

1
success

0
failure

Note: This function sets the location of the file in the local file system that contains the OAuth token that is required for authentication by the publish/subscribe server.

protobuffObjPtr C_dfESPpubsubInitProtobuff(char *_protoFile_, char *_msgName_, C_dfESPschema _C_schema_, char *_dateFormat_, C_dfESPeventcodes _defaultOpcode_)

Parameters:

protoFile
Path to the Google .proto file that contains the message definition.

msgName
Name of the target message definition in the Google .proto file.

C_schema
Pointer to the window schema.

dateFormat
Date format for CSV conversions. Set to null to interpret ESP_DATETIME and ESP_TIMESTAMP field values as an integer number of seconds (ESP_DATETIME) or microseconds (ESP_TIMESTAMP) since epoch.

defaultOpcode
The opcode to insert into events that are built from a serialized protobuf.

Return value:

A pointer to a `protobuff` object, which is passed to all other `protobuff` API functions. NULL when there is a failure.

C_dfESPeventblock C_dfESPprotobuffToEb(protobuffObjPtr _protobuff_, void *_serializedProtobuff_)

Parameters:

protobuff
pointer to the object created by `C_dfESPpubsubInitProtobuff()`

serializedProtobuff
pointer to serialized `protobuff` received on a socket

Return value:

Event block pointer

void *C_dfESPebToProtobuff(protobuffObjPtr *protobuff*, C_dfESPeventblock *C_eb*, int32_t *index*)

Parameters:

protobuff
pointer to the object created by `C_dfESPpubsubInitProtobuff()`

C_eb
event block pointer

index
index of the event to convert in the event block

Return value: pointer to serialized `protobuff`

void C_dfESPdestroyProtobuff(protobuffObjPtr *protobuff*, void **serializedProtobuff*)

Parameters:

protobuff
pointer to the object created by `C_dfESPpubsubInitProtobuff()`

serializedProtobuff
pointer to serialized `protobuff` received on a socket

jsonObjPtr C_dfESPpubsubInitJson(C_dfESPschema *C_schema*, char **dateFormat* C_dfESPeventcodes *defaultOpcode*)

Parameters:

C_schema
pointer to the window schema

dateFormat
Date format for CSV conversions. Set to null to interpret ESP_DATETIME and ESP_TIMESTAMP field values as an integer number of seconds (ESP_DATETIME) or microseconds (ESP_TIMESTAMP) since epoch.

defaultOpcode
the opcode to insert into events that are built from JSON that contain no opcode field

Return value: A pointer to a JSON object, which is passed to all other JSON API functions. NULL when there is a failure.

C_dfESPeventblock C_dfESPjsonToEb(jsonObjPtr *json*, const char **serializedJson*, int32_t *maxEvents*)

Parameters:

json
pointer to the object created by `C_dfESPpubsubInitJson()`

serializedJson
pointer to a serialized JSON received on a socket

maxEvents
limit the number of events created to this value. A value of 0 means no limit.

Return value: event block pointer

void *C_dfESPebToJson(jsonObjPtr *json*, C_dfESPeventblock *C_eb*)

Parameters:

json
pointer to the object created by `C_dfESPpubsubInitJson()`

C_eb
event block pointer

Return value: pointer to a serialized JSON

C_dfESPeventblockV C_dfESPxmlToEb(xmlObjPtr *xml*, const char *serializedXml, int32_t *maxEvents*)

Parameters:

xml
pointer to the object created by `C_dfESPpubsubInitXml()`

serializedXml
pointer to serialized XML received on a socket

maxEvents
the maximum number of events processed. A value of 0 means no limit.

Return value: event block pointer

xmlObjPtr C_dfESPpubsubInitXml(C_dfESPschema *C_schema*, char **dateFormat*, C_dfESPeventcodes *defaultOpcode*)

Parameters:

C_schema
pointer to the window schema

dateFormat
date format for CSV conversions. Set to null to interpret ESP_DATETIME and ESP_TIMESTAMP field values as an integer number of seconds (ESP_DATETIME) or microseconds (ESP_TIMESTAMP) since epoch.

defaultOpcode
the opcode to insert into events that are build from XML that contain no opcode field

Return value: A pointer to an XML object. This pointer is passed to all other XML API functions. The value is null when there is a failure.

void *C_dfESPebToXml(xmlObjPtr *xml*, C_dfESPeventblock *C_eb*)

Parameters:

xml
pointer to the object created by `C_dfESPpubsubInitXml()`

C_eb
event block pointer

void *C_dfESPebToXml(xmlObjPtr *xml*, C_dfESPeventblock *C_eb*)	
Return value:	pointer to serialized XML

A C library provides a set of functions to enable client developers to analyze and manipulate the event stream processing objects from the application or server. These functions are a set of C wrappers around a small subset of the methods provided in the C++ Modeling API. With these wrappers, client developers can use C rather than C++. Examples of these objects are events, event blocks, and schemas. A small sampling of these calls follows. For the full set of calls, see the API reference documentation available at **`$DFESP HOME/doc/html`**.

To get the size of an event block:	`C_ESP_int32_t eventCnt = C_dfESPeventblock_getSize(eb);`
To extract an event from an event block:	`C_dfESPevent ev = C_dfESPeventblock_getEvent(eb, eventIndx);`
To create an object (a string representation of schema in this case):	`C_ESP_utf8str_t schemaCSV =  C_dfESPschema_serialize(schema);`
To free an object (a vector of strings in this case):	`C_dfESPstringV_free(metaVector);`

Using the Java Publish/Subscribe API

Overview to the Java Publish/Subscribe API

SAS Event Stream Processing and its C publish/subscribe API use the SAS logging library, whereas the Java publish/subscribe API uses the Java logging APIs in the **`java.util.logging`** package. Please refer to that package for log levels and specifics about Java logging.

The Java publish/subscribe API is provided in two packages. These packages define the following public interfaces:

- **`com.sas.esp.api.pubsub`**
  - **`com.sas.esp.api.pubsub.clientHandler`**
  - **`com.sas.esp.api.pubsub.clientCallbacks`**
- **`com.sas.esp.api.server`**
  - **`com.sas.esp.api.server.datavar`**
  - **`com.sas.esp.api.server.event`**
  - **`com.sas.esp.api.server.eventblock`**
  - **`com.sas.esp.api.server.library`**
  - **`com.sas.esp.api.server.schema`**

A client can query the Event Stream Processor application or server at any time to discover currently running windows, continuous queries, and projects in various granularities. This information is returned to the client in

the form of a list of strings that represent names. This list can be used to build URL strings to pass to `subscriberStart()` or `publisherStart()`.

Note: If an event stream publishing URL that is passed to the Java API contains a `?username` parameter for authentication, you must include **`cas-client-*.jar`** in your classpath.

The parameters and usage for the Java publish/subscribe API are the same as for the equivalent calls for the C publish/subscribe API.

The C API references and Java interface references are available at **`$DFESP_HOME/doc/html`**.

Using High-Level Publish/Subscribe Methods

The following high-level publish/subscribe methods are defined in the following interface reference: **`com.sas.esp.api.pubsub.clientHandler`**.

Method	Description
`boolean init(Level level)`	Initialize publish/subscribe services
`dfESPclient publisherStart(String serverURL, clientCallbacks userCallbacks, Object ctx)`	Start a publisher.
`dfESPclient subscriberStart(String serverURL, clientCallbacks userCallbacks, Object ctx)`	Start a subscriber
`boolean connect(dfESPclient client)`	Connect to the Event Stream Processor application or server
`boolean publisherInject((dfESPclient client, dfESPeventblock eventblock)`	Publish event blocks
ArrayList< String > *queryMeta* (String *queryURL*)	Query model metadata
ArrayList< String > getModel(String *queryURL*)	Query model windows and their edges
`boolean disconnect (dfESPclient client, boolean block)`	Disconnect from the event stream processor
`boolean stop (dfESPclient client, boolean block)`	Stop a subscriber or publisher
`void shutdown ()`	Shutdown publish/subscribe services
`boolean setBufferSize(dfESPclient client, int mbytes)`	Change the default socket read and write buffer size
`dfESPclient GDsubscriberStart (String serverURL, clientCallbacks userCallbacks, Object ctx, String configFile)`	Start a guaranteed delivery subscriber
`dfESPclient GDpublisherStart (String serverURL, clientCallbacks userCallbacks, Object ctx, String configFile)`	Start a guaranteed delivery publisher

Method	Description
`long GDpublisherGetID()`	Get a sequentially unique ID to write to an event block to be published using guaranteed delivery
`boolean GDsubscriberAck(dfESPclient client, dfESPeventblock eventblock)`	Trigger a guaranteed delivery acknowledgment
`boolean persistModel(String hostportURL, String persistPath)`	Instruct a running engine to persist its current state to disk
`boolean quiesceProject(String projectURL, dfESPclient client)`	Instruct a running engine to quiesce a specific project in the model.
`boolean subscriberMaxQueueSize(String serverURL, int maxSize, boolean block)`	Configure the maximum size of the queues in the event stream processing server that are used to enqueue event blocks sent to subscribers. Set **`block`** to 1 to wait for queue size to fall below**`maxSize`**, else disconnect the client.
`boolean pingHostPort(String hostportURL)`	Pings a running engine to see whether the specified publish/subscribe port is open. Also, exchanges and verifies a magic number in order to confirm that the open port is a publish/subscribe port.
`boolean setTokenLocation(String tokenLocation)`	Sets the location of the file in the local file system that contains the OAuth token required for authentication by the publish/subscribe server.

For more information, see **`$DFESP_HOME/doc/html/index.html`**. Search the **`Classes`** page for **`client handler`**.

Using Methods That Support Google Protocol Buffers

The following methods support Google Protocol Buffers. They are defined in this interface reference: **`com.sas.esp.api.pubsub.protobufInterface`**.

Method	Description
`boolean init(String fileDescriptorSet, String msgName, dfESPschema schema, EventOpcodes defaultOpcode)`	Initialize the library that supports Google Protocol Buffers.
`dfESPeventblock protobufToEb(byte[] serializedProtobuf)`	Convert a `protobuf` message to an event block.
`byte[] ebToProtobuf(dfESPeventblock eb, int index)`	Convert an event in an event block to a `protobuf` message.

For more information, see Publish/Subscribe API Support for Google Protocol Buffers on page 26.

Using User-supplied Callback Functions

The **com.sas.esp.api.pubsub.clientCallbacks** interface reference defines the signatures of the user-supplied callback functions. There currently are three functions:

- the subscribed event block handler
- the publish/subscribe failure handler
- the guaranteed delivery ACK-NACK handler

The subscribed event block handler is used only by subscriber clients. It is called when a new event block from the application or server arrives. After processing the event block, the client is responsible for freeing it by calling `eventblock_destroy()`.

The signature of this user-defined callback is as follows:

```
void com.sas.esp.api.pubsub.clientCallbacks.dfESPsubscriberCB_func
     (dfESPeventblock eventBlock, dfESPschema schema, Object ctx)
```

- *eventBlock* is the event block just read
- *schema* is the schema of the event for client processing
- *ctx* is an optional context pointer for maintaining call state

The second callback function for publish/subscribe client error handling is optional for both subscriber and publisher clients. If supplied (that is, not NULL), it is called for every occurrence of an abnormal event within the client services, such as an unsolicited disconnect. This enables the client to gracefully handle and possibly recover from publish/subscribe services errors. The signature for this callback function is below where

- `failure` is either `pubsubFail_APIFAIL`, `pubsubFail_THREADFAIL`, or `pubsubFail_SERVERDISCONNECT`.
- `code` provides the specific code of the failure.
- `ctx` is an optional context pointer to a state data structure.

```
void com.sas.esp.api.pubsub.clientCallbacks.dfESPpubsubErrorCB_func
     (clientFailures failure, clientFailureCodes code, Object ctx)
```

clientFailures and client FailureCodes are defined in interface references **com.sas.esp.api.pubsub.clientFailures** and **com.sas.esp.api.pubsub.clientFailureCodes**.

The guaranteed delivery ACK-NACK handler is invoked to provide the status of a specific event block, or to notify the publisher that all subscribers are connected and publishing can begin. The signature for this callback function is as follows:

```
void com.sas.esp.api.pubsub.clientCallbacks.dfESPGDpublisherCB_func
   (clientGDStatus eventBlockStatus, long eventBlockID, Object ctx)
```

where

- `eventBlockStatus` is either ESP_GD_READY, ESP_GD_ACK, or ESP_GD_NACK
- `eventBlockID` is the ID written to the event block prior to publishing
- `ctx` is an optional context pointer to a state data structure

Using Alternative Transport Libraries for Java Clients

Alternative transport libraries enable a Java publish/subscribe client application to send and receive event blocks through a mechanism other than a direct TCP/IP connection to the client:

- Rabbit MQ Java libraries enable sending and receiving through the Rabbit MQ server.

- Solace Java libraries enable sending and receiving through the Solace appliance.
- Tervela Java libraries enable sending and receiving through the Tervela appliance.
- Kafka Java libraries enable sending and receiving through the Kafka cluster.

These libraries enable the Java equivalent of the C publish/subscribe API method, substituting an alternate transport. When the engine is configured for 1 + N-Way Failover using Rabbit MQ, Solace, Tervela, or Kafka, Java publish/subscribe clients must use the corresponding client library to guarantee successful failover.

To substitute one of these libraries in your Java publish/subscribe client application, insert the corresponding JAR filename in front of **dfx-esp-api.jar** in your classpath, as shown here:

- For Rabbit MQ, the JAR file is **dfx-esp-rabbitmq-api.jar** .
- For Solace, the JAR file is **dfx-esp-solace-api.jar** .
- For Tervela, the JAR file is **dfx-esp-tervela-api.jar** .
- For Kafka, the JAR file is **dfx-esp-kafka-api.jar** .

When you are using the Rabbit MQ library, you must also install the native Rabbit MQ Java client libraries (**rabbitmq-client.jar**) on your system. Obtain them at http://www.rabbitmq.com/java-client.html. Then add **rabbitmq-client.jar** to your classpath along with **commons-configuration-1.10.jar**, **commons-lang-2.6.jar**, and **commons-logging-1.2.jar** from **$DFESP_HOME/lib**.

When you are using the Kafka library, you must also install the native Kafka Java client libraries (**kafka-clients-*.jar**) on your system. Obtain them at http://kafka.apache.org/downloads.html. Then add **kafka-clients-*.jar** to your classpath along with **commons-configuration-1.10.jar**, **commons-lang-2.6.jar**, and **commons-logging-1.2.jar** from **$DFESP_HOME/lib**.

Your current working directory must also include a corresponding configuration file as shown here:

- For RabbitMQ this file must be named **rabbitmq.cfg**.
- For Solace, it must be named **solace.cfg**.
- For Tervela, it must be named **client.config**.
- For Kafka, it must be named **kafka.cfg**.

Here is a sample configuration file for RabbitMQ:

```
{
rabbitmq =
{
host = "my.machine.com";
port = "5672";
exchange = "SAS";
userid = "guest";
password = "guest";
passwordencrypted = false;
}
sas =
{
buspersistence = false;
queuename = "subpersist";
protobuf = false;
descfile = "./GpbHistSimFactory.desc";
protomsg = "GpbTrade";
noreplay = false;
}
}
```

Note: If `passwordencrypted = true`, the value in **`password`** must be the encrypted password generated by this OpenSSL command:

```
echo "password" | openssl enc -e -aes-128-cbc -a -salt -pass pass:"SASespRMQclientUsedByUser=userid"
```

The `buspersistence` and `queuename` parameters mean different things for publishers and subscribers.

- For a publisher, `queuename` is always ignored. If `buspersistence = false`, messages are sent in non-persistent delivery mode. Otherwise, delivery mode is persistent.
- For a subscriber, `buspersistence = false` means that all queues and exchanges created by the client are non-durable and auto-delete and that the `queuename` parameter is ignored. If `buspersistence = true`, all exchanges and queues are durable and not auto-delete and the `queuename` in the durable receive queue is fixed.

The `noreplay` parameter is false by default. When set to true, received messages are acknowledged even when `buspersistence` is enabled.

Here is a sample configuration file for Solace:

```
{
solace =
{
session = ( "host", "10.37.150.244:55555",
"username", "sub1", "password",
"sub1", "vpn_name", "SAS");
context = ( "CONTEXT_TIME_RES_MS", "50",
"CONTEXT_CREATE_THREAD", "1" );
}
sas=
{
buspersistence = false;
queuename = "myqueue";
protobuf = false;
descfile = "./GpbHistSimFactory.desc";
protomsg = "GpbTrade";
passwordencrypted = false;
}
}
```

Note: If `passwordencrypted = true`, the value in **`session.password`** must be the encrypted password generated by this OpenSSL command:

```
echo "session.password" | openssl enc -e -aes-128-cbc -a -salt -pass pass:"SASespSOLclientUsedByUser=session.user
```

Here is a sample configuration file for Tervela:

```
USERNAME esp
PASSWORD esp
PRIMARY_TMX 10.37.8.175
LOGIN_TIMEOUT 45000
GD_CONTEXT_NAME tvaIF
GD_MAX_OUT 10000
PASSWORDENCRYPTED        0
```

Note: If `PASSWORDENCRYPTED = 1`, the value in **`PASSWORD`** must be the encrypted password generated by this OpenSSL command:

```
echo "PASSWORD" | openssl enc -e -aes-128-cbc -a -salt -pass pass:"SASespTVAclientUsedByUser=USERNAME"
```

Here is a sample configuration file for Kafka:

```
{
kafka =
```

```
{
hostport = "kafkahost:9092"
partition = "0"
initialoffset = "largest"
groupid = "mygroup"
}
sas =
{
protobuf = false;
descfile = "./GpbHistSimFactory.desc";
protomsg = "GpbTrade";
}
}
```

Using the Python Publish/Subscribe API

The SAS Event Stream Processing Python publish/subscribe API was developed and tested using Python 2.7.x. Other versions might work, but they are untested and unsupported

The API is implemented using the Python ctypes foreign function library. This library wraps the C publish/subscribe API in Python. Thus, the Python Publish/Subscribe API definition mirrors the C Publish/Subscribe API. Functions have the same names as their C counterparts, but with “C_dfESPpubsub” removed from the name. The API is defined and documented in two files: pubsubApi.py and modelingApi.py. You can find these files in **`$DFESP_HOME/lib`**. You can find examples of publisher and subscriber clients written in Python at SAS Event Stream Processing Samples and Tips.

The `Init()` function does the following:

- loads the required C API libraries
- sets the Python function pointers
- creates an ESP logger instance
- calls the C API `C_dfESPpubsubInit()` function with the logging level and logging configuration file path passed to the Python `Init()` function
- returns the return value returned by `C_dfESPpubsubInit()`

modelingApi.py contains the following extra functions that do not wrap a C API function:

- `getLogger()`
- `arrayGetString(instance, i)`
- `arrayGetInt32(instance, i)`

`getLogger()` returns the Python logger instance created by `Init()`. A Python client can obtain the logger instance like this:

```
logger = logging.getLogger()
logger.addHandler(modelingApi.getLogger())
```

The logger defines internal function pointers to the standard ESP logging functions, so logged messages look like messages logged by an ESP server or C client. Messages can be logged at various levels by calling `logger.`*`level`*`(`*`string`*`)`, where *level* is **`debug`**, **`info`**, **`warning`**, **`error`**, or **`critical`**. These levels map to SAS Stream Processing logging levels DEBUG, INFO, WARN, ERROR, and FATAL respectively.

The `arrayGet*` functions are used to extract entries in an array built by a C function and returned by a Python function, such as `SchemaGetNames()`. This extraction is different from processing a vector built by a C

function, such as that returned by `QueryMeta()`. Entries in such a vector can be obtained by calling `StringVGet()`.

Publish/Subscribe API Support for Google Protocol Buffers

Overview to Publish/Subscribe API Support for Google Protocol Buffers

SAS Event Stream Processing provides a library to support Google Protocol Buffers. This library provides conversion methods between an event block in binary format and a serialized Google protocol buffer (`protobuf`).

To exchange a `protobuf` with an event stream processing server, a publish/subscribe client using the standard publish/subscribe API can call `C_dfESPpubsubInitProtobuff()` to load the library that supports Google Protocol Buffers. Then a publisher client with source data in `protobuf` format can call `C_dfESPprotobuffToEb()` to create event blocks in binary format before calling `C_dfESPpublisherInject()`. Similarly, a subscriber client can convert a received events block to a `protobuf` by calling `C_dfESPebToProtobuff()` before passing it to a `protobuf` handler.

Note: The server side of an event stream processing publish/subscribe connection does not support Google Protocol Buffers. It continues to send and receive event blocks in binary format only.

The SAS Event Stream Processing Java publish/subscribe API contains a `protobuf` JAR file that implements equivalent methods for Java publish/subscribe clients. In order to load the library that supports Google Protocol Buffers, you must have installed the standard Google Protocol Buffers run-time library. The SAS Event Stream Processing run-time environment must be able to find this library. For Java, you must have installed the Google `protobuf` JAR file and have included it in the run-time class path.

A publish/subscribe client connection exchanges events with a single window using that window's schema. Correspondingly, a `protobuf` enabled client connection uses a single fixed `protobuf` message type, as defined in a message block in a **`.proto`** file. The library that supports Google Protocol buffers dynamically parses the message definition, so no precompiled message-specific classes are required. However, the Java library uses a **`.desc`** file instead of a **`.proto`** file, which requires you to run the Google **`protoc`** compiler on the **`.proto`** file in order to generate a corresponding **`.desc`** file.

For C clients, the name of the **`.proto`** file and the enclosed message are both passed to the library that supports Google Protocol Buffers in the `C_dfESPpubsubInitProtobuff()` call. This call returns a `protobuf` object instance, which is then passed in all subsequent `protobuf` calls by the client. This instance is specific to the `protobuf` message definition. Thus, it is valid as long as the client connection to a specific window is up. When the client stops and restarts, it must obtain a new `protobuf` object instance.

For Java clients, the process is slightly different. The client creates an instance of a `dfESPprotobuf` object and then calls its `init()` method. Subsequent `protobuf` calls are made using this object's methods, subject to the same validity scope described for the C++ `protobuf` object.

Conversion between a binary event block and a `protobuf` is accomplished by matching fields in the `protobuf` message definition to fields in the schema of the associated publish/subscribe window. Ensure that the `protobuf` message definition and the window schema are compatible. When the `protobuf` message definition contains optional fields, ensure that they are included in the window schema. If a received `protobuf` message is missing an optional field, the corresponding field in the event is set to null. Conversely, when building a `protobuf` and a field of an event contains null, the corresponding `protobuf` field is left unset, and therefore must be defined as optional in the **`.proto`** file.

The following mapping of event stream processor to Google Protocol Buffer data types are supported:

Event Stream Processor Data Type	Google Protocol Buffer Data Type
ESP_DOUBLE	TYPE_DOUBLE TYPE_FLOAT
ESP_INT64	TYPE_INT64 TYPE_UINT64 TYPE_FIXED64 TYPE_SFIXED64 TYPE_SINT64
ESP_INT32	TYPE_INT32 TYPE_UINT32 TYPE_FIXED32 TYPE_SFIXED32 TYPE_SINT32 TYPE_ENUM
ESP_UTF8STR	TYPE_STRING
ESP_DATETIME	TYPE_INT64
ESP_TIMESTAMP	TYPE_INT64
Other mappings are currently unsupported.	

Converting Nested and Repeated Fields in Protocol Buffer Messages to an Event Block

Provided that they are supported, you can repeat the message fields of a `protobuf`. A message field of TYPE_MESSAGE can be nested, and possibly repeated as well. All of these cases are supported when converting a `protobuf` message to an event block, observing the following policies:

- A `protobuf` message that contains nested messages requires that the corresponding schema be a flattened representation of the `protobuf` message. For example, a `protobuf` message that contains three fields where the first is a nested message with four fields, the second is not nested, and the third is a nested message with two fields requires a schema with 4 + 1 + 2 = 7 fields. Nesting depth is unbounded.
- A single `protobuf` message is always converted to an event block that contains a single event, provided that no nested message field is repeated.
- When a `protobuf` message has a non-message type field that is repeated, all the elements in that field are gathered into a single comma-separated string field in the event. For this reason, any schema field that corresponds to a repeated field in a `protobuf` message must have type ESP_UTF8STR, regardless of the field type in the `protobuf` message.
- A `protobuf` message that contains nested message fields that are repeated is always converted to an event block that contains multiple events. There is one event for each element in every nested message field that is repeated.

Converting Event Blocks to Protocol Buffer Messages

Converting an event block to a `protobuf` is conceptually similar to converting nested and repeated fields in a `protobuf` to an event block, but the process requires more code. Every event in an event block is converted to a separate `protobuf` message. For this reason, the `C_dfESPebToProtobuff()` library call takes an index parameter that indicates which event in the event block to convert. The library must be called in a loop for every event in the event block.

The conversion correctly loads any nested fields in the resulting `protobuf` message. Any repeated fields in the resulting `protobuf` message contain exactly one element, because event blocks do not support repeated fields.

Note: Event block to `protobuf` conversions support only events with the Insert opcode, because event opcodes are not copied to `protobuf` messages. Conversions of `protobuf` to event blocks use the opcode that is specified in the C `C_dfESPpubsubInitProtobuff()` function or Java `init()` function. When protobufs are invoked by a connector or adapter, the opcode is Insert unless the connector or adapter is configured to use Upsert.

Support for Transporting Google Protocol Buffers

Support for Google Protocol Buffers is available when you use the connectors and adapters that are associated with the following message buses:

- IBM WebSphere MQ
- Rabbit MQ
- Solace
- Tervela
- Tibco/RV
- Kafka

These connectors and adapters support transport of a `protobuf` through the message bus, instead of binary event blocks. This allows a third-party publisher or subscriber to connect to the message bus and exchange a `protobuf` with an engine without using the publish/subscribe API. The `protobuf` message format and window schema must be compatible.

The connector or adapter requires configuration of the **`.proto`** file and message name through the **`protofile`** and **`protomsg`** parameters. The connector converts a `protobuf` to and from an event block using the SAS Event Stream Processing library that supports Google Protocol Buffers. In addition, the C and Java Solace publish/subscribe clients also support Google Protocol Buffers when configured to do so in the **`solace.cfg`** client configuration file. Similarly, C RabbitMQ and Kafka publish/subscribe clients support Google Protocol Buffers when they are configured to do so in the **`rabbitmq.cfg`** or **`kafka.cfg`** client configuration file. A `protobuf` enabled client publisher converts an event block to a `protobuf` to transport through the message bus to a third-party consumer of Google Protocol Buffers. Likewise, a `protobuf`-enabled client subscriber receives a `protobuf` from the message bus and converts it to an event block.

Publish/Subscribe API Support for JSON Messaging

Overview

SAS Event Stream Processing provides a C library to support JSON messaging. The library provides conversion methods between an event block in binary format and a serialized JSON message.

To exchange a JSON message with an event stream processing server, a publish/subscribe client that uses the standard publish/subscribe API can call `C_dfESPpubsubInitJson()` to load the library that supports JSON. Then a publisher client with source data in JSON format can call `C_dfESPjsonToEb()` to create event blocks in binary format. It can then call `C_dfESPpublisherInject()`.

Similarly, a subscriber client can convert a received events block to a JSON message by calling `C_dfESPebToJson()` before passing it to a JSON message handler.

Note: The server side of an event stream processing publish/subscribe connection does not support JSON messages. It continues to send and receive event blocks in binary format only.

A publish/subscribe client connection exchanges events with a single window using that window's schema. Correspondingly, a JSON-enabled client connection exchanges messages with a fixed JSON schema. However, there is no static definition of this schema. A schema mismatch between a JSON message and the related window schema is detected only at run time.

The `C_dfESPpubsubInitJson()` call returns a JSON object instance, which is then passed in all subsequent JSON calls by the client. This object instance is valid only while the client connection to a specific window is up. When the client stops and restarts, it must obtain a new JSON object instance.

Fundamentally, a single JSON message maps to a single event. However, a JSON message can contain multiple events when you enclose them within a JSON array.

Converting Nested Fields in JSON Messages to an Event Block

The window schema must be a flattened representation of the JSON event schema, where window field names are a concatenation of any nested JSON tag names, separated by underscores. When the input JSON contains fields that are intentionally missing in the source window schema and should be ignored, call the `C_dfESPignoreMissingSchemaFields()` method before building event blocks. This prevents the library from logging errors.

Within a JSON event schema, unlimited nesting of arrays and objects is supported.

When a JSON event contains an array field, all the elements in that array are gathered into a single comma-separated string field in the event. For this reason, any schema field that corresponds to an array field in a JSON event must have type `ESP_UTF8STR`, regardless of the field type within the JSON event schema.

The event built from a JSON event always has the Insert opcode. The exception is when the JSON event contains a field named `opcode`. In that case, the value of that field is used to set the event opcode. When other JSON fields do not match fields in the source window schema, the inject operation fails.

Valid Values for the Opcode Field in a JSON Event

Value	Opcode
`i` `I`	Insert
`u` `U`	Update
`d` `D`	Delete
`p` `P`	Upsert
`s` `S`	Safe delete

By default, the event block is `type= normal`. When events in an event block array are contained within an additional array (that is, enclosed in an additional pair of brackets), the event block is `type= transactional`.

You can configure the JSON library to filter out JSON values that do not contain a configured substring. In this case, the corresponding event is silently dropped. You can enable such filtering by configuring the `matchsubstrings` parameter and supplying a comma separated string of ***`key:substring`*** pairs. For example, a configured value of `"foo:bar"` means that a JSON key "foo" that does not contain "bar" in its value does not generate an event stream processing event. When you configure multiple substrings per key, input JSON data must contain only one of the configured substrings in order to generate an event.

When no JSON field (or combination of fields) can easily be used as a key for the source window, add one or both of the following key fields to the source window schema:

`"`*`eventindex`*`*:int64,`*`adapterindex`*`*:string"`

When present in the source window schema, the library fills in these fields as follows:

- *eventindex*: a 64-bit atomic integer that is incremented for every event, and is guaranteed unique across multiple instances of the library in a process space.
- *adapterindex*: a GUID string that is guaranteed unique for instances of the library running in different process spaces.

The combination of these values allows multiple users of the library in different processes to inject events into a single source window without duplicating keys.

When you require static JSON values to be included in all injected events, pass it to the `C_dfESPaddStaticJson()` method. All subsequent events include fields built from that JSON.

Converting Event Blocks to JSON Messages

All JSON events that are created from an event contain an `opcode` field. Valid values are listed in Valid Values for the Opcode Field in a JSON Event on page 30.

Because the input is an event block, the resulting JSON message always has an array as its root object. Each array entry represents a single event.

Data variable type `ESP_MONEY` is not supported.

Data variable types `ESP_TIMESTAMP` and `ESP_DATETIME` are converted to a JSON string that contains the CSV representation of the field value.

Support for Transporting JSON Messages

Support for JSON messaging is available when you use the connectors and adapters associated with the following message buses:

- IBM WebSphere MQ
- RabbitMQ
- Solace
- Tervela
- Tibco/RV
- Kafka

These connectors and adapters support transport of JSON encoded messages through the message bus, instead of binary event blocks. This enables a third-party publisher or subscriber to connect to the message bus and exchange JSON messages with an engine without using the publish/subscribe API.

No message-format configuration is required. If the JSON schema and window schema are incompatible, a publisher that converts JSON to event blocks fails when an event block is injected. The connector converts JSON to and from an event block using the SAS Event Stream Processing library that supports JSON conversion.

C RabbitMQ, Solace Systems, and Kafka publish/subscribe clients support JSON when configured to do so in the **`rabbitmq.cfg`**, **`solace.cfg`**, or **`kafka.cfg`** client configuration files. A JSON-enabled client publisher converts an event block to a JSON message to transport through the message bus to a third-party consumer of JSON messages. Likewise, a JSON enabled client subscriber receives a JSON message from the message bus and converts it to an event block.

Publish/Subscribe API Support for XML Messaging

SAS Event Stream Processing provides a C library to support XML messaging. This library is analogous to the JSON messaging library described previously. It provides the following API functions:

- `C_dfESPpubsubInitXml()`
- `C_dfESPxmlToEb()`
- `C_dfESPebToXml()`
- `C_dfESPaddStaticXml()`
- `C_dfESPignoreMissingSchemaFields()`

These functions perform the same operations as the corresponding JSON functions in the JSON library.

Guaranteed Delivery

Overview to Guaranteed Delivery

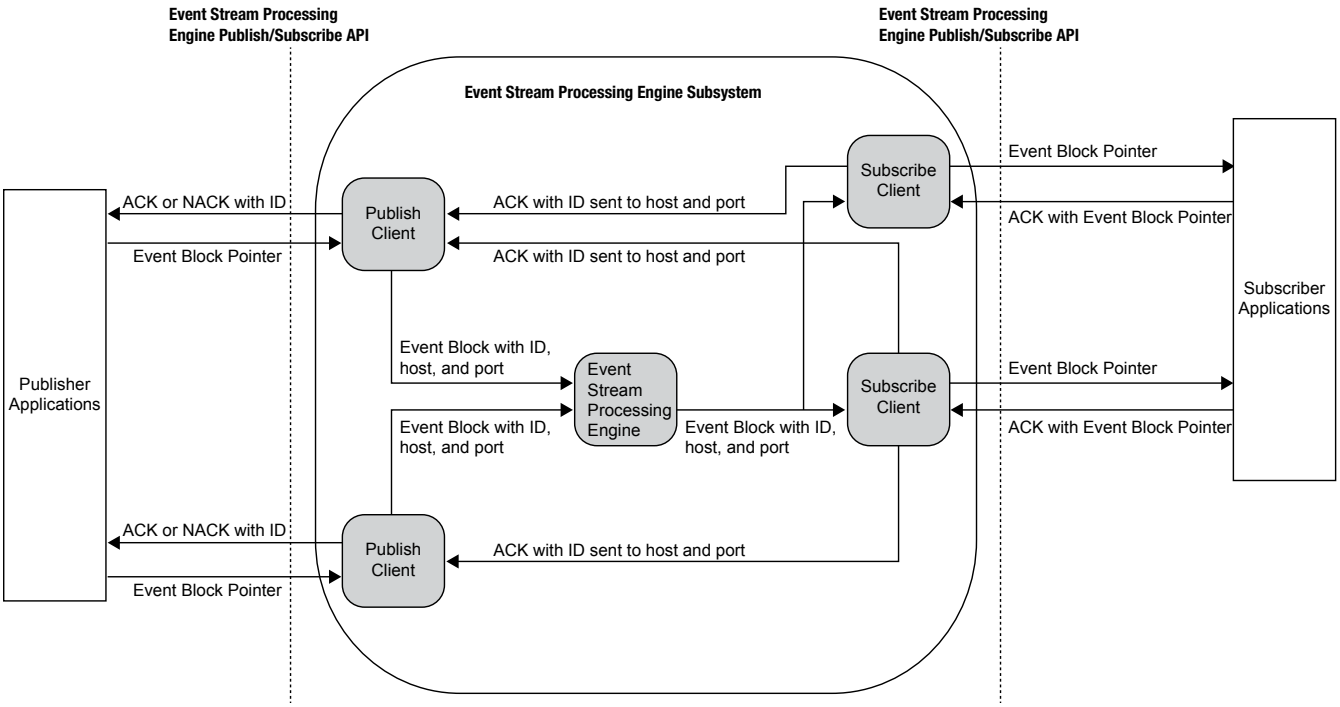
The C, Java, and Python Publish/Subscribe APIs support guaranteed delivery between a single publisher and multiple subscribers. Guaranteed delivery assumes a model where each event block that is published into a source window generates exactly one event block in a subscribed window. This one block in, one block out principle must hold for all published event blocks. The guaranteed delivery acknowledgment mechanism is not aware of the event processing performed by the model.

When a publish or subscribe connection is started, a client is established to perform various publish/subscribe activities. When a publish connection is started, the number of guaranteed subscribers required to acknowledge delivery of its event blocks is specified. The time-out value used to generate negative acknowledgments upon non-receipt from all expected subscribers is also specified. Every event block injected by the publisher contains a unique 64-bit ID set by the publisher. This ID is passed back to the publisher from the publish client with every acknowledgment or negative acknowledgment in a publisher user-defined callback function. The function is registered when the publish client is started.

When a subscribe connection is started, the subscribe client is passed a set of guaranteed delivery publishers as a list of host and port entries. The client then establishes a TCP connection to each publisher on the list. This connection is then used only to transport acknowledgments specific to this publisher/subsciber pair. The subscriber calls a new Publish/Subscribe API function to trigger an acknowledgment.

Event blocks contain new host, port, and ID fields. All event blocks are uniquely identified by the combination of these fields. This enables subscribers to identify duplicate (that is, resent) event blocks.

Guaranteed Delivery Data Flow Diagram



Please note the following:

- Publishers and subscribers that do not use the guaranteed-delivery-enabled API functions are implicitly guaranteed delivery disabled.
- Guaranteed delivery subscribers can be mixed with non-guaranteed delivery subscribers.
- A guaranteed delivery-enabled publisher might wait to begin publishing until a READY callback has been received. This indicates that its configured number of subscribers have established their acknowledgment connections back to the publisher.
- Event blocks received by a guaranteed-delivery-enabled subscriber as a result of a snapshot generated by the engine are not acknowledged.
- Under certain conditions, subscribers receive duplicate event blocks. These conditions include the following:
  - A publisher begins publishing before all related subscribers have started. Any started subscriber can receive duplicate event blocks until the number of started subscribers reaches the number of required acknowledgments passed by the publisher.
  - A guaranteed delivery-enabled subscriber disconnects while the publisher is publishing. This triggers the same scenario described previously.
  - A slow subscriber causes event blocks to time-out, which triggers a negative acknowledgment to the publisher. In this case all subscribers related to the publisher receives any resent event blocks, including those that have already called `C_dfESPGDsubscriberAck()` for those blocks.
- If a guaranteed delivery-enabled subscriber fails to establish its acknowledgment connection, it retries at a configurable rate up to a configurable maximum number of retries.
- Suppose that a guaranteed delivery-enabled publisher injects an event block that contains an ID, and that the ID is present in the publish client's not acknowledged-ID list. In that case, the inject call is rejected by the publish client. The ID is cleared from the list when the publish client passes it to the ACK/NACK callback function of the new publisher.

Guaranteed Delivery Success Scenario

In the context of guaranteed delivery, the publisher and subscriber are customer applications that are the endpoints in the data flow. The subscribe and publish clients are event stream processing code that implements the publish/subscribe API calls made by the publisher and subscriber.

The flow of a guaranteed delivery success scenario is as follows:

1. The publisher passes an event block to the publish client, where the ID field in the event block has been set by the publisher. The publish client fills in the host-port field, adds the ID to its unacknowledged ID list, and injects it to the engine.
2. The event block is processed by the engine and the resulting Inserts, Updates, or Deletes on subscribe windows are forwarded to all subscribe clients.
3. A guaranteed delivery-enabled subscribe client receives an event block and passes it to the subscriber by using the standard subscriber callback.
4. Upon completion of all processing, the subscribers call a new API function with the event block pointer to trigger an acknowledgment.
5. The subscribe client sends the event block ID on the guaranteed delivery acknowledgment connection that matches the host or port in the event block, completely bypassing the engine.
6. Upon receipt of the acknowledgment, the publish client increments the number of acknowledgments received for this event block. If that number has reached the threshold passed to the publish client at start-up, the

publish client invokes the new guaranteed delivery callback with parameters acknowledged and ID. It removes the ID from the list of unacknowledged IDs.

Guaranteed Delivery Failure Scenarios

There are three failure scenarios for guaranteed delivery flows:

Scenario	Description
Event Block Time-out	■ An event block-specific timer expires on a guaranteed-delivery-enabled publish client, and the number of acknowledgments received for this event block is below the required threshold. ■ The publish client invokes the new guaranteed delivery callback with parameters `NACK` and `ID`. No further retransmission or other attempted recovery by the publish client or subscribe client is undertaken for this event block. The publisher most likely backs out this event block and resends. ■ The publish client removes the ID from the list of unacknowledged IDs.
Invalid Guaranteed Delivery Acknowledged Connect Attempt	■ A guaranteed-delivery-enabled publish client receives a connect attempt on its guaranteed delivery acknowledged server but the number of required client connections has already been met. ■ The publish client refuses the connection and logs an error message. ■ For any subsequent event blocks received by the guaranteed delivery-enabled subscribe client, an error message is logged.
Invalid Event Block ID	■ A guaranteed-delivery-enabled publisher injects an event block that contains an ID already present in the publish client's unacknowledged ID list. ■ The inject call is rejected by the publish client and an error message is logged.

Additions to the Publish/Subscribe API for Guaranteed Delivery

The publish/subscribe API provides the following methods to implement guaranteed delivery sessions:

- `C_dfESPGDpublisherStart()`
- `C_dfESPGDsubscriberStart()`
- `C_dfESPGDsubscriberAck()`
- `C_dfESPGDpublisherCB_func()`
- `C_dfESPGDpublisherGetID()`

For more information, see . For publish/subscribe operations without a guaranteed delivery version of the function, call the standard publish/subscribe API function.

Configuration File Contents

The publish client and subscribe client reads a configuration file at start-up to get customer-specific configuration information for guaranteed delivery. The format of both of these files is as follows.

Guaranteed Delivery-enabled Publisher Configuration File Contents	
Local port number for guaranteed delivery acknowledgment connection server.	
Time-out value for generating negative acknowledgments, in seconds.	
Number of received acknowledgments required within time-out period to generate positive instead of negative acknowledgments.	

File format:	`GDpub_port=<port>`
	`GDpub_timeout=<timeout>`
	`GDpub_numSubs=<number of subscribers generating acknowledged>`

Guaranteed Delivery-enabled Subscriber Configuration File Contents	
List of guaranteed delivery-enabled publisher host or port entries. Each entry contains a host:port pair corresponding to a guaranteed delivery-enabled publisher from which the subscriber wishes to receive guaranteed delivery event blocks.	
Acknowledgment connection retry interval, in seconds.	
Acknowledgment connection maximum number of retry attempts.	

File Format:	`GDsub_pub=<host:port>`
	`GDsub_retryInt=<interval>`
	`GDsub_maxRetries=<max>`