Server Programming Guide

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Software designed and built in Australia by BigWorld.

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Part I. Server Scripting Guide

Table of Contents

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Chapter 1. Overview

This part of the document contains technical information for creating entities and user data objects for the BigWorld Server. It is part of a larger set of documentation describing the whole BigWorld system.

The intended audience is technical-typically MMOG developers and designers.

For API-level information, please refer to the API reference documentation.

Note
For details on BigWorld terminology, see the document Glossary of Terms.

Chapter 2. Physical Entity Structure for Scripting

Entities are the objects that make up the game world. Using entities, you can create players, NPCs, loot, chat rooms, and many other interactive elements in your games.

Each entity type is implemented as a collection of Python scripts, and an XML-based definition file that ties the scripts together. These scripts are located in the resource tree under the folder `scripts` (*i.e.*, `<res>/scripts` , where `<res>` is the virtual tree defined `~/.bwmachined.conf`).

The list below summarises the important files and directories for entities in `<res>`:

- **`<res>`** - Resource tree defined in `~/.bwmachined.conf` .
  - **`scripts`** - Folder containing all entity files.
    - **`db.xml`** - Persistent state for the XML database system.
    - **`entities.xml`** - Lists all entities to load into the client or the server at start-up time.
    - **`base`** - Folder contains Python scripts for entities with a base component.
    - **`cell`** - Folder contains Python scripts for entities with a cell component.
    - **`client`** - Folder contains Python scripts for entities with a client component.
    - **`common`** - Folder listed in the Python search path for all components. Used for common game code.
      - **`lib`** - Folder listed in the Python search path for all components. Used for common game code.
    - **`entity_defs`** - Contains an XML `.def` file for each entity listed in file `<res>/scripts/entities.xml`.
      - **`alias.xml`** - Data types aliases used in the project.
      - **`<entity>.def`** - Entity definition file. There is one such file for each entity defined in `<res>/scripts/entities.xml`.
      - **`interfaces`** - Entity interface definition files
  - **`server`** - System-wide settings.
    - Default values for the system.

2.1. The entities.xml File

The file `<res>/scripts/entities.xml` is used by the BigWorld engine to determine the types of entities available for use.

Each tag in this file represents an entity type, and must have a corresponding definition file in the directory `<res>/scripts/entity_defs`, and at least one Python script file in either the `<res>/scripts/base` or `<res>/scripts/cell` directory. It may also have a script file in `<res>/scripts/client`.

The order in which the entity types are declared in this file corresponds to the final entity ID associated with each entity type.

In its simplest form, the entities file has one tag listed for each entity to be loaded.

To define an entity called `NewEntityType`, simply add a line like the one below:

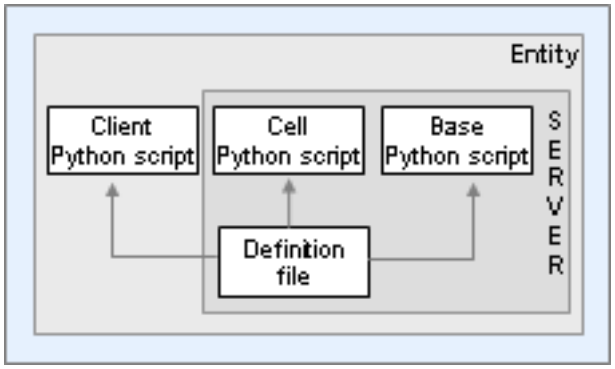
```
<root>
  ...
  <NewEntityType/>
</root>
```

<res>/scripts/entities.xml - Entity definition

2.2. The Entity Definition File

The entity definition file <res>/scripts/entity_defs/<entity>.def determines how your scripts communicate in BigWorld. This allows the BigWorld system to abstract the tasks of sending and receiving messages into simply calling different script methods on your entities. In a sense, the definition file provides an interface to your entity, and the Python scripts provide the implementation.

The following diagram shows the conceptual parts of a BigWorld entity:



Conceptual parts of an entity

Each entity type has a corresponding definition file, named after the entity's type name followed by the extension '.def'. For example, a Seat entity type would have a file called Seat.def.

It is useful then, to have a 'minimal' definition file to aid in quickly defining a new entity, as well as to assist in explaining what the document's section is trying to accomplish.

The following file is a minimal entity definition file:

```
<root>

  <Parent> optional parent entity </Parent> 1

  <Implements> 2
     <!-- interface references -->
   </Implements>

  <ClientName> optional client type </ClientName> 3

  <Volatile> 4
     <!-- volatile definitions -->
   </Volatile>

   <Properties> 5
     <!-- properties -->
   </Properties>

  <ClientMethods> 6
     <!-- declaration -->
```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```
    </ClientMethods>

   <CellMethods> 7
      <!-- declaration -->
    </CellMethods>

   <BaseMethods> 8
      <!-- declaration -->
    </BaseMethods>

   <LoDLevels> 9
     <!-- levels of detail -->
    </LODLevels>

</root>
```

<res>/scripts/entity_defs/<entity>.def - Minimal entity definition file

1 For details, see "Entity Parents" on page 56 .
2 For details, see "Entity Interfaces" on page 54 .
3 For details, see "Client Entity Reuse" on page 57 .
4 For details, see "Volatile Properties" on page 35 .
5 For details, see *Properties* on page 17 .
6 For details, see *Methods* on page 41 .
7 For details, see *Methods* on page 41 .
8 For details, see *Methods* on page 41 .
9 For details, see "LOD (Level of Detail) on Properties" on page 37 .

By the end of this chapter, we should be able to replace all placeholders (denoted by italics) in the example file above with actual code.

2.3. The Script Files

BigWorld Technology divides processing of entities in a game world into three different execution contexts:

Entity type	Script file location	Description
Cell	<res>/scripts/cell	Takes care of the portions of an entity that affect the space around it. Processing takes place on the server cluster.
Base	<res>/scripts/base	Takes care of the portions of an entity that do not affect the space around it (as well as possibly acting as a proxy for a player). Processing takes place on the server cluster.
Client	<res>/scripts/client	Takes care of the portions of an entity that require heavy awareness of the surrounding environment.

It is possible for some entity instances to not have one of these three parts. Furthermore, some entity types may not support ever having one of these parts. For each entity type, there is a script file for each of CellApp, BaseApp, and Client, if that type supports that execution context.

These script files are named after the entity type, followed by the extension '`.py`'. This file must contain a class with the name of the entity type.

For example, if you have an entity type `Seat` that can have cell, base and client execution contexts, there would be three script files, each with the implementation of the class:

- <res>/scripts/cell/Seat.py

- `<res>/scripts/base/Seat.py`
- `<res>/scripts/client/Seat.py`

The entity's base class defined in the script file is determined by the execution context that the file represents, as described below:

Script file execution context	Entity's base class
Cell	`BigWorld.Entity`
Base	`BigWorld.Base` **or** `BigWorld.Proxy`
Client	`BigWorld.Entity`

For more details about the difference between the `Base` and `Proxy` classes, see *Proxies and Players* on page 83 .

The start of the script for a `Seat` entity could be implemented as below:

- **Cell script file - `<res>/scripts/cell/Seat.py`**

```
import BigWorld

class Seat( BigWorld.Entity ):
  def __init__( self ):
    BigWorld.Entity.__init__( self )
```

- **Base script file - `<res>/scripts/base/Seat.py`**

```
import BigWorld

class Seat( BigWorld.Base ):
  def __init__( self ):
    BigWorld.Base.__init__( self )
```

- **Client script file - `<res>/scripts/client/Seat.py`**

```
import BigWorld

class Seat( BigWorld.Entity ):
  def __init__( self ):
    BigWorld.Entity.__init__( self )
```


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Chapter 3. Physical User Data Object Structure for Scripting

User data objects are a way of embedding user defined data in Chunk files. Each user data object type is implemented as a collection of Python scripts, and an XML-based definition file that ties the scripts together. These scripts are located in the resource tree under the folder `scripts` (i.e., `<res>/scripts`, where `<res>` is the virtual tree defined `~/.bwmachined.conf`).

User data objects differ from entities in that they are immutable (i.e. their properties don't change), and that they are not propagated to other cells or clients. This makes them a lot lighter than entities.

A key feature of user data objects is their linkability. Entities are able to link to user data objects, and user data objects are able to link to other user data objects. This is achieved by including a `UDO_REF` property in the definition file for the user data object or entity that wishes to link to another user data object.

The list below summarises the important files and directories for user data objects in `<res>`:

- **`<res>`** — Resource tree defined in `~/.bwmachined.conf`.
  - **`scripts`** — Folder containing all entity files.
    - **`user_data_objects.xml`** — Lists all user data objects to load into the client or the server at start-up time.
    - **`base`** — Folder contains Python scripts for user data objects with a base component.
    - **`cell`** — Folder contains Python scripts for user data objects with a cell component.
    - **`client`** — Folder contains Python scripts for user data objects with a client component.
    - **`common`** — Folder listed in the Python search path for all components. Used for common game code.
      - **`lib`** — Folder listed in the Python search path for all components. Used for common game code.
    - **`user_data_object_defs`** — Contains the user data object definition files.
      - **`<user_data_object.def>`** — User data object definition file. There is one such file for each user data object defined in `<res>/scripts/user_data_objects.xml`.
      - **`interfaces`** — User data object interface definition files

3.1. The user_data_objects.xml File

The file `<res>/scripts/user_data_objects.xml` is used by the BigWorld engine to determine the types of user data objects available for use.

The file structure matches that of the `<res>/entities/entities.xml`. For further details refer to “The entities.xml File” on page 11

3.2. The User Data Object Definition File

The user data object definition file `<res>/scripts/user_data_object_defs/<user_data_object>.def` determines the properties it will store and make accessible to BigWorld entities. The user data object definition file also specifies if the user data object should be created in the server or in the client.

The following file is a minimal entity definition file:

```
<root>

  <Domain> the execution context for this user </Domain> 1

  <Parent> optional parent entity </Parent> 2

  <Implements> 3
     <!-- interface references -->
   </Implements>

   <Properties> 4
     <!-- properties -->
   </Properties>

</root>
```

<res>/scripts/user_data_object_defs/*<user_data_object>*.def — Minimal user data object definition file

1 The domain for a user data object can be either CLIENT, CELL or BASE.
2 For details, see “Entity Parents” on page 56 .
3 For details, see “Entity Interfaces” on page 54 .
4 For details, see *Properties* on page 17 .

3.3. The Script Files

BigWorld Technology divides processing of entities in a game world into three different execution contexts, depending on its Domain:

- **User Data Object Domain: Cell — Script File Location: *<res>*/scripts/cell**

  User data objects to be used by entities in the cell.

- **User Data Object Domain: Base — Script File Location: *<res>*/scripts/base**

  User data objects to be used by entities in the base.

- **User Data Object Domain: Client — Script File Location: *<res>*/scripts/client**

  User data objects to be used by entities in the client.

Most implementations of user data objects will only live either in the cell or in the client. For an example of a user data object that lives in the cell, see the PatrolNode user data object scripts and definition file in the *<res>*/scripts folder. For an example of a client-only user data object, look in the same place for the scripts and definition file of the CameraNode user data object.

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Chapter 4. Properties

Properties describe what the state of an entity is. Like traditional object systems, a BigWorld property has a type and a name. Unlike traditional object systems, a property also has distribution properties that affect where and how frequently it is distributed around the system.

Properties are declared in the entity's definition file (named `<res>/scripts/entity_defs/<entity>.def`), in a section named `Properties`.

The grammar for property definition is displayed below:

```
<root>
   ...
   <Properties>
      <propertyName>
         <!-- type of this property -->
         <Type> TYPE_NAME </Type> 1

         <!-- Method of distribution -->
         <Flags> DISTRIBUTION_FLAGS </Flags> 2

         <!-- Default value (optional) -->
         <Default> DEFAULT_VALUE </Default> 3

         <!-- Is the property editable? (true/false) (optional) -->
         <Editable> [true|false] </Editable>

         <!-- Level of detail for this property (optional) -->
         <DetailLevel> LOD </DetailLevel> 4

         <!-- Is the property persistent? -->
         <Persistent> [true|false] </Persistent> 5

      </propertyName>
   </Properties>
   ...
</root>
```

`<res>/scripts/entity_defs/<entity>.def` — Property definition syntax

1 For details, see “Property Types” on page 17 .
2 For details, see “Data Distribution” on page 26 .
3 For details, see “Default Values” on page 23 .
4 For details, see “LOD (Level of Detail) on Properties” on page 37 .
5 For details, see *The Database Layer* on page 66 .

4.1. Property Types

BigWorld needs to efficiently transmit data over a network between its various components. For this purpose, BigWorld definition file describes the type of each property of an entity (despite the fact that BigWorld is scripted using Python — an untyped language).

Because bandwidth conservation is important in implementing an MMOG, property types should be selected such that they are the smallest type (in terms of number of bits) that can represent the data.

4.1.1. Primitive Types

The following list summarises the primitive types available for BigWorld properties:

- **`BLOB` — Size (bytes): *N*+*k***

  Binary data. Similar to a string, but can contain NULL characters.

  Stored in base-64 encoding when in XML, *e.g.*, in the XML database.

  N is the number of bytes in the blob, and *k*=4.

- **`FLOAT32` — Size (bytes): 4**

  IEEE 32-bit floating-point number.

- **`FLOAT64` — Size (bytes): 8**

  IEEE 64-bit floating-point number.

- **`INT8` — Size (bytes): 1 — Range: From: -128 To: 127**

  Signed 8-bit integer.

- **`INT16` — Size (bytes): 2 — Range: From: -32,768 To: 32,767**

  Signed 16-bit integer.

- **`INT32` — Size (bytes): 4 — Range: From: -2,147,483,648 To: 2,147,483,647**

  Signed 32-bit integer.

- **`INT64` — Size (bytes): 8 — Range: From: -9,223,372,036,854,775,808 To: 9,223,372,036,854,775,807**

  Signed 64-bit integer.

- **`MAILBOX` — Size (bytes): 12**

  A BigWorld mailbox.

  Passing an entity to a `MAILBOX` argument automatically converts it to `MAILBOX`.

  For details, see “Mailboxes” on page 47 .

- **`PYTHON` — Size(bytes): Size of pickled string, as per `STRING`**

  Uses the Python pickler to pack any Python type into a string, and transmits the result.

  This should not be used between client and server, as it is insecure and inefficient.

  It is recommended to use a user data type for production code. For more details, see “Implementing Custom Property Data Types” on page 30 .

- **`STRING` — Size (bytes): *N*+*k***

  Character string.

  N is the number of characters in the string, and *k*=4.

- **`UINT8` — Size(bytes): 1 - Range: From: 0 To: 255**

  Unsigned 8-bit integer.

- **`UINT16` — Size(bytes): 1 — Range: From: 0 To: 65,535**

  Unsigned 16-bit integer.

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- **`UINT32` — Size(bytes): 1 — Range: From: 0 To: 4,294,967,295**

  Unsigned 32-bit integer.

  This type may use Python's `long` type instead of `int`, and so might be less efficient than `INT32`.

- **`UINT64` — Size(bytes): 1 — Range: From: 0 To: 18,446,744,073,709,551,615**

  Unsigned 64-bit integer.

- **`VECTOR2` — Size(bytes): 8**

  Two-dimensional vector of 32-bit floats. Represented in Python as a tuple of two numbers (or `Math.Vector2`).

- **`VECTOR3` — Size(bytes): 12**

  Three-dimensional vector of 32-bit floats. Represented in Python as a tuple of three numbers (or `Math.Vector3`).

- **`VECTOR4` — Size(bytes): 16**

  Four-dimensional vector of 32-bit floats. Represented in Python as a tuple of four numbers (or `Math.Vector4`).

4.1.2. Composite Types

The following sections describe the composite types available in BigWorld.

4.1.2.1. ARRAY and TUPLE Types

BigWorld also has ARRAY and TUPLE types, which can create an array of values of any of the BigWorld primitive types.

Properties of ARRAY type have a byte size calculated by the formula below:

$$N * t + k$$

The components of the formula are described below:

- **`N`** — Number of elements in the array.
- **`t`** — Size of the type contained in the array.
- **`k`** — Constant.

The BigWorld TUPLE type is represented in script by the Python tuple type, while the BigWorld ARRAY type is represented in script by Python list type.

Tuples are specified as follows:

```
<Type> TUPLE <of> [TYPE_NAME|TYPE_ALIAS] </of> [<size> n </size>] </Type>
```

`<res>/scripts/entity_defs/<entity>.def` — TUPLE declaration syntax

Arrays are specified as follows:

```
<Type> ARRAY <of> [TYPE_NAME|TYPE_ALIAS] </of> [<size> n </size>] </Type>
```

<*res*>/scripts/entity_defs/<*entity*>.def — ARRAY declaration syntax

In case the size of an ARRAY or TUPLE is specified, then it must have the declared *n* elements. Adding or deleting elements to fixed-sized ARRAY or TUPLE is not allowed. If the default value is not specified, then a fixed-sized ARRAY or TUPLE will contain *n* default values of the element type.

Arrays can not only contain aliased data types, but may also be aliased themselves. For more details, see "Alias of Data Types" on page 22 .

4.1.2.2. FIXED_DICT Data Type

The FIXED_DICT data type allows you to define dictionary-like attributes with a fixed set of string keys. The keys and the types of the keyed values are predefined.

The declaration of a FIXED_DICT is illustrated below:

```
<Type> FIXED_DICT

  <Parent> ParentFixedDictTypeDeclaration </Parent>
   <Properties>

    <field>
      <Type> FieldTypeDeclaration </Type>
     </field>

   </Properties>

  <AllowNone> true|false </AllowNone> 1

</Type>
```

FIXED_DICT data type declaration

1 Default is false. If set to true, then None may be used as the value of the whole dictionary.

This data type may be declared anywhere a type declaration may appear, *e.g.*, in <*res*>/scripts/entity_defs/alias.xml [1], in <*res*>/scripts/entity_defs/<*entity*>.def, as method call arguments, etc.

The code excerpt below shows the declaration of a FIXED_DICT attribute:

```
<root>
  <TradeLog> FIXED_DICT
    <Properties>
      <dbIDA>
        <Type>      INT64                </Type>
      </dbIDA>
      <itemsTypesA>
        <Type>      ARRAY <of> ITEM </of> </Type>
      </itemsTypesA>
      <goldPiecesA>
        <Type>      GOLDPIECES           </Type>
      </goldPiecesA>
    </Properties>
  </TradeLog>
</root>
```

[1] For details on this file's grammar, see the document File Grammar Guide's section alias.xml

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fantasydemo/res/scripts/entity_defs/alias.xml

Instances of FIXED_DICT can be accessed and modified like a Python dictionary, with the following exceptions:

- Keys cannot be added or deleted
- The type of the value must match the declaration.

For example:

```
if entity.TradeLog[ "dbIDA" ] == 0:
  entity.TradeLog[ "dbIDA" ] = 100
```

Example of FIXED_DICT usage in script

Alternatively, it also supports the following:

```
if entity.TradeLog.dbIDA == 0:
  entity.TradeLog.dbIDA = 100
```

Example of FIXED_DICT usage as struct in script

A FIXED_DICT instance can be set using a Python dictionary that has a superset of the keys required. Any unnecessary keys in the dictionary are ignored.

For example:

```
entity.TradeLog = { "dbIDA" : 100, "itemsTypesA" : [ 1, 2, 3 ],
     "goldPiecesA" : 1000, "redundantKey" : 12345 }
```

Example of FIXED_DICT instance being set using a Python dictionary

When setting a FIXED_DICT instance using a Python dictionary, the values of the Python dictionary are referenced by the FIXED_DICT instance.

Note

When setting a FIXED_DICT instance using a Python dictionary in the BaseApp, the Python dictionary replaces the FIXED_DICT instance. Thus, the entire Python dictionary is being referenced, not just its values.
As a result of this behaviour, there is the possibility of FIXED_DICT attribute having more keys than in its declaration.
This BaseApp behaviour may be changed in a future release of BigWorld so that it matches the rest of the system.

Changes to FIXED_DICT values are propagated efficiently wherever a change to the whole property would be propagated, *i.e.*, to ghosts and to clients — including ownClients.

The default value of a FIXED_DICT data type can be specified at the entity property level. For example:

```
<root>
  <Properties> FIXED_DICT
    <someProperty>
      <Type>  TradeLog    </Type>    <!-- From last example -->
```

```
      <Default>
        <dbIDA>  0  </dbIDA>
        <itemsTypesA>
          <item>  101  </item>
          <item>  102  </item>
        </itemsTypesA>
        <goldPiecesA>  100  </goldPiecesA>
      </Default>
    </someProperty>
  </Properties>
</root>
```

Example of specifying default value of a FIXED_DICT data type in an entity definition file

If the <Default> section is not specified, then the default value of a FIXED_DICT data type will depend on the value of the <allowNone> tag, as described below:

<AllowNone>	FIXED_DICT default value
True	Python None object.
False	Python dictionary with keys as specified in the type definition. Each keyed value will have a default value according to its type. For example, a keyed value of INT type will have a default value of 0.

4.1.3. Custom User Types

There are two ways to incorporate user-defined Python classes into BigWorld entities: wrapping a FIXED_DICT data type, or implementing a USER_TYPE.

The FIXED_DICT data type supports being wrapped by a user-defined Python type. When a FIXED_DICT is wrapped, BigWorld will instantiate the user-defined Python type in place of a FIXED_DICT instance. This enables the user to customise the behaviour of a FIXED_DICT data type.

The type system can also be arbitrarily extended with the USER_TYPE type. Unlike a wrapped FIXED_DICT type, the structure of a USER_TYPE type is completely opaque to BigWorld. As such, the implementation of a USER_TYPE type is more involved. The implementation of the type operations is performed by a Python object (such as an instance of a class) written by the user. The Python object serves as a factory and serialiser for instances of that type, and it can choose to use whatever Python representation of that type it sees fit — it can be as simple as an integer, or it can be an instance of a Python class.

For more details on custom user types, see “Implementing Custom Property Data Types” on page 30 .

4.1.4. Alias of Data Types

BigWorld also allows aliases of types to be created. Aliases are a concept similar to a C++ typedef, and are listed in the XML file *<res>*/scripts/entity_defs/alias.xml. The format is described below:

```
<root>
  ... other alias definitions ...
  <ALIAS_NAME> TYPE_TO_ALIAS [<Default> Value </Default>1 ] </ALIAS_NAME>
</root>
```

<res>/scripts/entity_defs/alias.xml — Data type alias declaration syntax

1 For details, see “Default Values” on page 23 .

Some examples of useful aliases are described in the list below:

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Alias	Maps to	Description
ANGLE	FLOAT32	An angle measured in radians.
BOOL	INT8	A Boolean type (encoded as zero=false, non-zero=true). Mapped to INT8, the smallest BigWorld type.
INFO	UINT16	Element of information about a mission.
MISSION_STATS	ARRAY <of> INFO </of>	Array of mission information data elements (*i.e.*, INFO type alias). Note that this is an aliased array, and the type of its elements is an aliased type.
OBJECT_ID	INT32	Handle to another entity. The name makes clear the property contains a handle to an entity.
STATS_MATRIX	ARRAY <of> MISSION_STATS </of>	Matrix of mission information data elements (*i.e.*, INFO type alias). Note that this is an aliased array, and the type of its elements is another aliased array.

Using the syntax for alias definition to the aliases describe above, we have the following file:

```
<root>

  <!-- Aliased data types -->
  <OBJECT_ID>  INT32   </OBJECT_ID>
  <BOOL>       INT8    </BOOL>
  <ANGLE>      FLOAT32 </ANGLE>
  <INFO>       UINT16  </INFO>

  <!-- Aliased arrays ?
  <MISSION_STATS>  ARRAY <of> INFO           </of> </MISSION_STATS>
  <STATS_MATRIX>   ARRAY <of> MISSION_STATS  </of>  </STATS_MATRIX>

</root>
```

<res>/scripts/entity_defs/alias.xml — Definition of data type alias

With aliases, one can also define custom Python data types, which have their own streaming semantics on the network. We declare these types in the file <res>/scripts/entity_defs/alias.xml file as follows:

```
<root>
  <ALIAS_NAME>
    USER_TYPE
    <implementedBy> UserDataType.instance </implementedBy>
  </ALIAS_NAME>
</root>
```

<res>/scripts/entity_defs/alias.xml — Custom Python data type declaration syntax

For more details on this mechanism, see “Implementing Custom Property Data Types” on page 30 .

4.2. Default Values

When an entity is created, its properties are initialised to their default values. Default values can be overridden at the property level (in the entity definition file[2]) or at the type level (in alias.xml[3]).

The default value for each type and the syntax for overriding it are described below:

[2]For details, see the introduction to this chapter.

[3]For details on this file's grammar, see the document File Grammar Guide's section alias.xml.

- **ARRAY — Default: []**

  Example:

```
<Default> 1
   <item> Health potion </item>
   <item> Bear skin     </item>
   <item> Wooden shield </item>
</Default>
```

  1 Constructs the equivalent Python list `[ 'Health potion', 'Bear skin', 'Wooden shield' ]`.

- **BLOB — Default: ''**

  Example:

```
<Default> SGVsbG8gV29ybGQhB </Default> 1
<!-Hello World! -->
```

  1 BASE6-encoded string value must be specified.

- **FIXED_DICT**

  For details, see “FIXED_DICT Data Type” on page 20 .

- **FLOAT32 — Default: 0.0**

  Example:

```
<Default> 1.234 </Default>
```

- **FLOAT64 — Default: 0.0**

  Example:

```
<Default> 1.23456789 </Default>
```

- **INT8, INT16, INT32, INT64 — Default: 0**

  Example:

```
<Default> 99 </Default>
```

- **MAILBOX — Default: None**

  Default value cannot be overridden.

- **PYTHON — Default: None**

  Example:

```
<Default>
  { "Strength": 90, "Agility": 77 }
```


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```
</Default>
```

- **`STRING` — Default: `''`**

  Example:

  ```
  <Default> Hello World! </Default> 1
  ```

  1 Value must be specified without quotes.

- **`TUPLE` — Default: `()`**

  Example: See ARRAY data type

- **`UINT8`, `UINT16`, `UINT32`, `UINT64` — Default: `0`**

  Example:

  ```
  <Default> 99 </Default>
  ```

- **`USER_TYPE` — Default: Return value of the user-defined `defaultValue()` function.**

  Example:

  ```
  <Default>
     <intVal>  100       </intVal>
     <strVal>  opposites </stringVal>
     <dictVal>
        <value>
           <key>   good    </key>
           <value> bad     </value>
        </value>
     </dictValue>
  </Default>
  ```

- **`VECTOR2` — Default: `PyVector` of `0.0` of the appropriate length.**

  Example:

  ```
  <Default> 3.142 2.71 </Default>
  ```

- **`VECTOR3` — Default: `PyVector` of `0.0` of the appropriate length.**

  Example:

  ```
  <Default> 3.142 2.71 1.4 </Default>
  ```

- **`VECTOR4` — Default: `PyVector` of `0.0` of the appropriate length.**

  Example:

  ```
  <Default> 3.142 2.71 1.4 3.8 </Default>
  ```

4.3. Data Distribution

Properties represent the state of an entity. Some states are only relevant to the cell, others only to the base, and yet others only to the client. Some states, however, are relevant to more than one of these.

Each property then has a distribution type that specifies to BigWorld which execution context (cell, base, or client) is responsible for updating the property, and where to propagate its value within the system.

Data distribution is set up by specifying the sub-section `<Flags>` of the section `<Properties>` in the file `<res>/scripts/entity_defs/<entity>.def`.

The bit flags available are defined in `src/lib/entitydef/data_description.hpp`, and are described in the list below:

- **`DATA_BASE`**

  Required flags: N/A — Excluded flags: `DATA_GHOSTED` — Master value on: Base

  Data will be updated on the base, and will not be available on the cell.

- **`DATA_GHOSTED`**

  Required flags: N/A — Excluded flags: `DATA_BASE` — Master value on: Cell

  Data will be updated on the cell, and will be ghosted on other cells.

  This means that it is safe to read the value of this property from another entity, because BigWorld safely makes it available even across cell boundaries.

- **`DATA_OTHER _CLIENT`**

  Required flags: `DATA_GHOSTED` — Excluded flags: N/A — Master value on: Cell

  Data will be updated on the cell, and made available to clients who have this entity in their AoI.

  This makes the property safe to read from the client for any entity, except for that client's player avatar entity. This flag is often combined with `DATA_OWN_CLIENT` to create a property that is distributed to all clients.

- **`DATA_OWN_CLIENT`**

  Required flags: N/A — Excluded flags: N/A — Master value on: Base, if `DATA_BASE` is set. Otherwise, on cell.

  Data is propagated to client owning this entity.

  This only makes sense with player entities.

The list below describes the valid combinations of the above bit flags:

- **`ALL_CLIENTS`**[A]

  Available to: Other cells, Cell, Own client, Other clients

  Property is available to all entities on cell and client.

  Corresponds to setting both `OWN_CLIENT` and `OTHER_CLIENTS` flags.

  Examples include:

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- The name of a player.
- The health status of a player or a creature.

- **`BASE`**

  Available to: Base

  Property is only available on the base.

  Examples include:

  - List of members of a chat room.
  - Items in a character's inventory.

- **`BASE_AND_CLIENT`**

  Available to: Base, Own client

  Property is available on the base and on the owning client. Corresponds to setting both `OWN_CLIENT` and `BASE` flags.

  Note

  Properties of this type are only synchronised when the client entity is created. Neither the client nor the base is automatically updated when property changes. Methods must be used to propagate new value, which is simple, since only one player needs to receive it.

- **`CELL_PRIVATE`**

  Available to: Cell

  Property is only available to its entity, and only on cell.

  Examples include:

  - Properties of an NPCs 'thoughts' in AI algorithms.
  - Player properties relevant to game play, but dangerous to allow players to see (*e.g.*, healing time after battle).

- **`CELL_PUBLIC`**

  Available to: Other cells, Cell

  Property is available only on the cell, and is available to other entities.

  Examples include:

  - The mana level of a player (which can be seen only by enemies, not by other players).
  - The call sign for grouping from enemy NPC.

- **`CELL_PUBLIC_AND_OWN`**

  Available to: Other cells, Cell, Own client

  Property is available to other entities on the cell, and to this one on both the cell and the client.

Unlike `OWN_CLIENT`, this data is also ghosted, and therefore available to other entities on the cell.

- **`DATA_EDITOR_ONLY`**

  Available to: WorldEditor

  This value may be useful when using `BigWorld.fetchEntitiesFromChunks` from a BaseApp. It could be used to decide programmatically whether a particular entity should be loaded.

  For example, you may associate a level of difficulty with each entity, so entity will only be loaded if the mission's level of difficulty is high enough.

- **`OTHER_CLIENTS`**[A]

  Available to: Other cells, Cell, Other clients

  Property is available from client to entities that are not this player's avatar. Also available on cell to other entities.

  Examples include:

  - The state of dynamic world items (*e.g.*, doors, loot containers, and buttons).
  - The type of a particle system effect.
  - The player who is currently sitting on a seat.

- **`OWN_CLIENT`**[A]

  Available to: Cell, Own client

  Property is only available to this entity, on both the cell and the client.

  Examples include:

  - The character class of a player.
  - Number of experience points for a player.

A *— When properties with this distribution flag are updated by server, an implicit method is called on client. For details,* *see "Implicit `set_<property_name>` Methods" on page 45 .*

The list below describes the deprecated data distribution constants:

Deprecated enumeration	Equivalent to
ALL_CLIENT	ALL_CLIENTS
CELL	CELL_PUBLIC
CELL_AND_OWN	CELL_PUBLIC_AND_OWN
GHOSTED	CELL_PUBLIC
GHOSTED_AND_OWN	CELL_PUBLIC_AND_OWN
OTHER_CLIENT	OTHER_CLIENTS
PRIVATE	CELL_PRIVATE

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When choosing a distribution flag for a property, consider the points described below:

- **Which methods need the property?**

  You have to make the property available on an execution context (cell, base, or client) if that context has a method that manipulates the property.

- **Does this property need to be accessed by other entities?**

  This could include methods being called to access its value. If this is the case, we need to make the property ghosted.

  When doing this, remember that the ghosted entities' properties may be a little 'lagged', *i.e.*, they may not represent the exact state of an entity at a given time. Also, remember that other entities can only read the property; only the entity that owns the property may change it.

- **Is the client interested in this value directly?**

  Client/server bandwidth is scarce, so the number of properties on the client needs to be minimised.

  Sometimes, a group of properties can be maintained on the cell and only a derived additional property needs to be sent to the client. For example, a client part would probably not need to know that a combination of six AI state variables are causing a guard to be angry; they would however need to know the derived value that the guard is brandishing an axe.

- **Could a player cheat by seeing this property?**

  If so, then care must be taken about sending it to the client.

- **There can only be one master value of any property.**

  The master value must reside on either the base or cell. Consequently, if the same property is available on both the base and the cell, the other holder of the property needs to have the value propagated to it via a method.

4.3.1. Data Propagation

Data propagation occurs when the entity is first created. Subsequent modifications to properties will only be local to the component, except when the modification occurs in a CellApp, in which case the change will be automatically propagated to all interested parties. For example, `CELL_PUBLIC` properties are propagated to all other CellApps that have a ghost of the entity, `OTHER_CLIENTS` properties are propagated to all clients that have the entity in their AoI, and so on.

When changing the value of a property in a component other than a CellApp, the change can be manually propagated using remote method calls. For details, see *Methods* on page 41 .

4.3.1.1. Forcing Data Propagation for Python and Custom User Types

Changes to properties of `PYTHON` and custom user types are not automatically propagated, unless the property is reassigned.

This behaviour mainly affects composite Python types like dictionaries, arrays, and classes, because modifications to the object do not cause data propagation unless the property is reassigned to itself.

For example, if entity *e* has the property as illustrated below:

```
<pythonProp>
```

```
  <Type> PYTHON </Type>
  ...
</pythonProp>
```

Assigning a new value to `pythonProp` will cause data propagation:

```
e.pythonProp = { 'gold': 100 }
```

However, modifying the value will not cause data propagation:

```
e.pythonProp[ 'gold' ] = 50
e.pythonProp[ 'arrows' ] = 200
```

Different parts of the entity will see different values for `pythonProp`, unless data propagation is manually triggered by reassigning the property back to itself:

```
e.pythonProp = e.pythonProp
```

4.4. Implementing Custom Property Data Types

Custom data types are useful for the implementation of data structures with complex behaviour that is shared between different components, or that must be attached to cell entities (in which case they must be able to be transferred from one cell to another).

4.4.1. Wrapping a FIXED_DICT Data Type

By default, the `FIXED_DICT` data type behaves like a Python dictionary. This behaviour can be changed by replacing the dictionary-like `FIXED_DICT` type with another Python type (referred to as a wrapper type in this document).

To do so, specify a type converter object in the `<implementedBy>` section in the `FIXED_DICT` type declaration. For example:

```
<Type>
  FIXED_DICT
  <implementedBy> CustomTypeConverterInstance  </implementedBy>
  <Properties> ... </Properties>
  ...
</Type>
```

Declaration of a Wrapped `FIXED_DICT` Data Type

`CustomTypeConverterInstance` must be a Python object that converts between `FIXED_DICT` instances and wrapper instances.

It must implement the following methods:

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Method	Description
`addToStream( self, obj )`	Optional method that converts a wrapper instance to a string suitable for transmitting over the network. The `obj` parameter is a wrapper instance. This method should return a string representation of `obj`. Typically, this is done using the `cPickle` module. If this method is present, then `createFromStream` must also be. If this method is not present, then wrapper instances are transmitted over the network by first converting them to `FIXED_DICT` instances using the `getDictFromObj` method, and then recreated at the receiving end using the `createObjFromDict` method.
`createFromStream( self, stream )`	Optional method that creates an instance of the wrapper type from its string network form. The `stream` parameter is a Python string obtained by calling the `addToStream` method. This method should return a wrapper instance constructed from the data in stream. If this method is present, then `addToStream` must also be provided.
`createObjFromDict( self, dict )`	Method to convert a `FIXED_DICT` instance to a wrapper instance. The `dict` parameter is a `FIXED_DICT` instance. This method should return the wrapper instance constructed from the information in `dict`.
`getDictFromObj( self, obj )`	Method to convert a wrapper instance to a `FIXED_DICT` instance. The `obj` parameter is a wrapper instance. This method should return a Python dictionary (or dictionary-like object) that contains the same set of keys as a `FIXED_DICT` instance.
`isSameType( self, obj )`	Method to check whether an object is of the wrapper type. The `obj` parameter in an arbitrary Python object. This method should return `True` if `obj` is a wrapper instance.

4.4.1.1. Example of Wrapping FIXED_DICT with a Class

It is often desirable to wrap a `FIXED_DICT` data type with a class to facilitate object-oriented programming.

```
import cPickle

class MyCustomType:          // wrapper type
  def __init__( self, dict ):
    self.a = dict[ "a" ]
    self.b = dict[ "b" ]
  ...                    // other MyCustomType methods

class MyCustomTypeConverter:    // type converter class
  def getDictFromObj( self, obj ):
    return { "a": obj.a, "b": obj.b }

  def createObjFromDict( self, dict ):
    return MyCustomType( dict )

  def isSameType( self, obj ):
    return isinstance( obj, MyCustomType )

  def addToStream( self, obj ):          // optional
    return cPickle.dumps( obj )

  def createFromStream( self, stream ):    // optional
    return cPickle.loads( stream )

instance = MyCustomTypeConverter()    // type converter object
```

`<res>/scripts/common/MyCustomTypeImpl.py` — Wrapper type and type converter object

```
<Type>
  FIXED_DICT
  <implementedBy> MyCustomTypeImpl.instance  </implementedBy>
  <Properties>
    <a> ... </a>
    <b> ... </b>
  </Properties>
  ...
</Type>
```

Excerpt of a wrapped FIXED_DICT type declaration

The above example makes a FIXED_DICT type behave as a class with members a and b, instead of as a dictionary with the same keys.

The drawback with the above example is that member updates are not automatically propagated to other components. For example, if the above data type is used in an entity attribute called custType, the following script code would only set the value of the attribute for the local copy of the entity:

```
e.custType.a = 100
e.custType.b = 200
```

To ensure that all copies of the entity e have the updated values, the attribute must be set to a different instance of MyCustomType with the updated values:

```
e.custType = MyCustomType( { "a": 100, "b": 200 } )
```

Alternatively, MyCustomType can be implemented using descriptors that reference the original FIXED_DICT instance:

```
class MemberProxy:              // descriptor class
  def __init__( self, memberName ):
    self.member = memberName

  def __get__( self, instance, owner ):
    instance.fixedDict[ self.memberName ]

  def __set__( self, instance, value ):
    instance.fixedDict[ self.memberName ] = value

  def __delete__( self, instance ):
    raise NotImplementedError( self.memberName )

class MyCustomClass:            // wrapper class
  a = MemberProxy( "a" )
  b = MemberProxy( "b" )

  def __init__( self, dict ):
    self.fixedDict = dict
  ...                       // other MyCustomType methods

class MyCustomTypeConverter:      // type converter class
  def getDictFromObj( self, obj ):
    return obj.fixedDict        // must return original instance

  def createObjFromDict( self, dict ):
    return MyCustomType( dict )
```


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```
def isSameType( self, obj ):
  return isinstance( obj, MyCustomType )

// addToStream and createFromStream cannot be implemented
```

<res>/scripts/common/MyCustomTypeImpl.py — Wrapper type and type converter object using descriptors

In the above example, `MyCustomClass` references the original `FIXED_DICT` instance in its `fixedDict` member. Access to members `a` or `b` will be redirected via the descriptor class to the `fixedDict` member. As updates to `FIXED_DICT` instances are automatically propagated to other components, updates to members `a` and `b` are also automatically propagated.

The drawback with this approach is that custom streaming is not possible. If the `addToStream` and `createFromStream` methods are implemented, then the custom object is created directly from the stream. Since it is not possible to instantiate a FIXED_DICT object in Python script, it will not be possible for the custom object to reference a FIXED_DICT object that will propagate partial changes.

4.4.1.2. Implementing a USER_TYPE Data Type

The `USER_TYPE` data type predates the `FIXED_DICT` data type, and much of its functionality can be achieved by wrapping a `FIXED_DICT` data type. However, `USER_TYPE` data type additionally allows customising its representation as a `<DataSection>`.

A `USER_TYPE` data type consists of the following pieces:

- A declaration of the Python instance implementing the `USER_TYPE` data type. For example:

  ```
  <Type> USER_TYPE <implementedBy> UserType.instance </implementedBy> </Type>
  ```

  <res>/scripts/entity_defs/<entity>.def — User type declaration syntax

  However, it is recommended to declare a `USER_TYPE` data type in `<res>/scripts/entity_defs/alias.xml` [4] to give it a name that we can use in the entity definition files [5] (named `<res>/scripts/entity_defs/<entity>.def`).

- A class that defines methods to read and write this data type from various places.
- A module, containing the above class, and an instance of this class, which will be used to serialise and unserialise the custom data type.

The custom data type might also declare a Python class that represents the type at runtime. A Python list, a dictionary, or some other native Python data type might also represent it.

The class we implement provides methods to serialise whatever Python type we use to represent a concept. This means that we can transmit the class over the network and serialise it to a database, simply by writing the appropriate methods in this class.

These methods are described in the list below:

Method	Description
`addToStream( self, obj )`	Converts the Python object obj into a string representation to be placed onto the network, and return that string. It does the opposite of `createFromStream`. The `struct` library from Python is useful in performing this task. For example, if your type contains a single `INT32` member, then `addToStream` could be implemented as: `def addToStream( self, obj ):`

Method	Description
	`return struct.pack( "i", obj )`

`createFromStream( self, stream )`	Creates a Python object from the string passed in through `stream`. It does the opposite of `addToStream`.
	The length of the `stream` must be checked before trying to unpack it.
	For example, if your type contains a single `INT32` member, then `createFromStream` could be implemented as:
	`def createFromStream( self, stream ):`
	`  if len(stream) != 4: # one integer`
	`  raise "Error: string has wrong length"`
	`  else:`
	`  return struct.unpack( "I", stream )`

`addToSection( self, obj, section )`	Adds a representation of `obj` to the section `<DataSection>`. It is used for persisting properties into the database. Hence, if a property is not persistent, this method does not have to be implemented.
`createFromSection( self, section )`	Creates and returns a Python object from its persisted representation in section `<DataSection>`. It is used for persisting properties into the database, and parsing default values from *`<res>`*`/scripts/entity_defs/`*`<entity>`*`.def` files. You should always implement this method, even if you do not implement `addToSection`.

`fromStreamToSection( self, stream, section )`	Converts data from a `stream` representation (a string) to a `<DataSection>` representation in `section`. It can be implemented as follows:
	`def fromStreamToSection( self, stream, section ):`
	`  o = self.createFromStream( stream )`
	`  self.addToSection( o, section )`
	It can also be implemented more efficiently (for instance if the `<DataSection>` representation is very similar to the stream representation). For example:
	`section.asBlob = stream`

`fromSectionToStream( self, section )`	Converts data from a `<DataSection>` representation in `section` to a stream representation, and returns it.
	It can be implemented as follows:
	`def fromSectionToStream( self, section ):`
	`  o = self.createFromSection( section )`
	`  return self.addToStream( o )`
	It can also be implemented more efficiently (for instance if the `<DataSection>` representation is very similar to the stream representation). For example:
	`return section.asBlob`

`defaultValue( self )`	Returns a reasonable default value for this data type. It is used when there is no default value specified when this data type is used in a property.

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We place a class implementing these methods into a module in the directory `<res>/scripts/common`, and create an instance variable as an instance of this class.

For example, we may define a module called `MyCustDataType.py`, as illustrated below:

```
class MyCustDataType:
  def addToStream( self, obj ):
    ...
  def createFromStream( self, stream ):
    ...
  def addToSection( self, obj, section ):
    ...
  def createFromSection( self, section ):
    ...
  def fromStreamToSection( self, stream, section ):
    ...
  def fromSectionToStream( self, section ):
    ...
  def defaultValue( self ):
    ...
instance = MyCustDataType()
```

`<res>/scripts/common/MyCustDataType.py` — Serialisation methods

If the property is persistent, and stored in a MySQL database, then an additional method has to be implemented. This method will declare the binding of the data into the database. For more details, see *The Database Layer* on page 66 .

The variable instance is the object that performs the manipulation of this data type by BigWorld. In the aliases file `<res>/defs/alias.xml`, we would include the following definition:

```
<root>
  ...
  <MY_CUSTOM_DATA_TYPE>
    USER_TYPE
    <implementedBy> MyCustDataType.instance </implementedBy>
  </MY_CUSTOM_DATA_TYPE>
```

`<res>/defs/alias.xml` — Definition of `MY_CUST_DATA_TYPE`

4.5. Volatile Properties

Some properties are updated more often than others, and almost all entities have a set of properties that need to be handled specially due to this. These properties are called *volatile* properties, and are pre-defined by the BigWorld engine.

The default volatile properties defined by BigWorld are outlined below:

Property	Description
`position`	The (x,y,z) position of the entity. Represented in Python as a `TUPLE` of three floats.

`yaw`
`pitch`
`roll`
	Three extra volatile properties, which are typically used for the direction an entity is facing, but may be used for other purposes. They still must, however, have the ranges of the corresponding element of a direction:
	# `(-pi,pi)` for `yaw`
	# `(-pi/2,pi/2)` for `pitch`
	# `(-pi/2,pi/2)` for `roll`

These properties are updated with an optimised protocol used between the client and the server, in order to minimise bandwidth.

The volatile properties are listed separately to the normal properties in the file `<res>/scripts/entity_defs/<entity>.def`.

Each entity can decide which of these volatile properties are automatically updated. Additionally, they can have a priority attached to them. This priority determines a distance from the entity above which the property is no longer sent.

The syntax is as follows:

```
<root>
  ...
  <Volatile>
    <position/> | <position>  float  </position>
    <yaw/>      | <yaw>       float  </yaw>
    <pitch/>    | <pitch>     float  </pitch>
    <roll/>     | <roll>      float  </roll>
  </Volatile>
  ...
```

`<res>/scripts/entity_defs/<entity>.def` — Declaration of volatile properties

This is how the volatility status and priority of a property are interpreted:

- If a property is not specified, then it will never be updated (`BigWorld.VOLATILE_NEVER`).
- If a property is specified:
  - If a priority is not specified, then property will always be updated, regardless of distance from entity (`BigWorld.VOLATILE_ALWAYS`).
  - If a priority is specified, then the value is used as the maximum distance from entity (in metres) for which property will still be updated.

Supposing an entity the volatile properties as defined below:

```
<root>
  ...
  <Volatile>
    <position/>
    <yaw>    30.0  </yaw>
    <pitch>  25.0  </pitch>
  </Volatile>
  ...
</root>
```

`<res>/scripts/entity_defs/<entity>.def` — Example definition

For the above example, we have the following for each property:

- `position` — Always updated (`BigWorld.VOLATILE_ALWAYS`)
- `yaw` — Updated up to a distance of 30.0 metres.
- `pitch` — Updated up to a distance of 25.0 metres.
- `roll` — Never updated (`BigWorld.VOLATILE_NEVER`)

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Note

Only non-moving entities should be defined without volatile properties.
Such entities will still behave as if all their properties were defined as volatile, and with priority `VOLATILE_ALWAYS`. This is required due to the necessity of being able to update a non-moving entity's properties when it is occasionally moved (*e.g.*, a chair has been slightly moved).

4.6. LOD (Level of Detail) on Properties

Sometimes bandwidth usage can be optimised even further, by not distributing information to clients that are distant. We can do this by attaching a `<DetailLevel>` tag to a property. This tag determines the distance after which property changes will not be sent to the client.

Note that this is purely an optimisation for the property. This option should only be used if bandwidth usage is proven to be too high. If this feature is enabled for the property, then you must test it very carefully to check if the result achieved in terms of game play is what you expected.

The definition of the LOD (level of detail) of a property in the file `<res>/scripts/entity_defs/<entity>.def` is described below:

```
<root>
  ...
  <Properties>
    ...
    <modelNumber>
      ...
      <DetailLevel> NEAR </DetailLevel>
    </modelNumber>
    ...
```

`<res>/scripts/entity_defs/<entity>.def` — Declaration of LOD for property

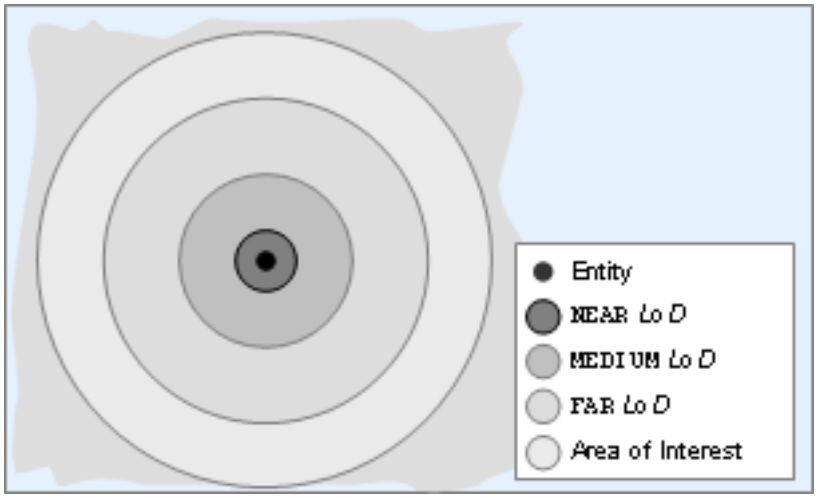
The example above declared a LOD labelled `NEAR` for the property. The actual value of `NEAR` is defined in the sub-section `<level>` of the section `<LodLevels>` in the entity's file.

For example, to subdivide the AoI into the ranges labelled `NEAR`, `MEDIUM`, and `FAR` (with everything further than `FAR` being transmitted whenever entities are within each other's AoI), the entity's definition file will include the lines below:

```
<root>
  ...
  <LODLevels>
    <level>  20  <label> NEAR    </label> </level>
    <level> 100  <label> MEDIUM  </label> </level>
    <level> 250  <label> FAR     </label> </level>
  </LODLevels>
  ...
</root>
```

`<res>/scripts/entity_defs/<entity>.def` — Definition of labels for LODs

The LODs specified for the entity in the example file above are illustrated below:



Location of LOD boundaries relative to the entity

Detail levels are inherited from parent definition files. Any level with the same label as a parent will modify that level, and any new levels will be added.

There is currently a limit of six levels of detail for each entity type

4.6.1. LOD and Hysteresis

In addition to its parameter `<label>`, the sub-section `<level>` can also have `<hyst>` parameter.

It is defined as illustrated in the example below:

```
<root>
  ...
  <LODLevels>
    <level>  20 <label> NEAR   </label> <hyst>  4 </hyst> </level>
    <level> 100 <label> MEDIUM </label> <hyst> 10 </hyst> </level>
    <level> 250 <label> FAR    </label> <hyst> 20 </hyst> </level>
  </LODLevels>
  ...
```

`<res>/scripts/entity_defs/<entity>.def` — Definition of hysteresis regions

This parameter defines a hysteresis region starting from the LOD's outer boundary and moving outwards. It prevents frequent changes in the LOD of a property, which saves significant processing time on the cell, as properties do not have to change their priorities often. In order to do this, the `<hyst>` specifies a buffer region around the boundary of a LOD level, which an entity must pass through completely before changing to a lower LOD.

The declaration of the `<hyst>` parameter is optional, and if not declared, it will default to 10 metres.

As an example, consider a stationary entity, and another entity travelling through points *A*, *B*, *C*, *D*, *E*, and finally back to *A*, as illustrated in the diagram below:

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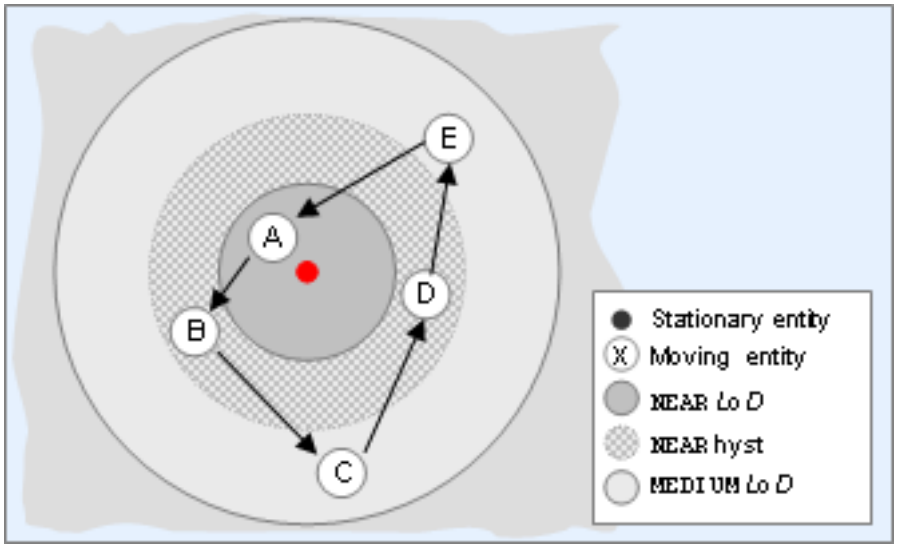

Entity moving around LODs of another entity

We consider the minimum LOD of properties that will be propagated from the moving entity to the stationary entity, as listed in the table below:

Point	LOD	Reason
A	NEAR	Unaffected by hysteresis.
B	NEAR	Entity has moved from NEAR to MEDIUM, but not yet completely through the hysteresis.
C	MEDIUM	Entity has moved from NEAR to MEDIUM, and completely through the hysteresis.
D	MEDIUM	Entity is still in MEDIUM.
E	MEDIUM	Entity is still in MEDIUM.
A	NEAR	Entity has moved from MEDIUM to NEAR.

In the example above, we have the following regarding the change of LOD for the moving entity:

- The change of LOD for the moving entity from NEAR to MEDIUM occurs at a distance of 24 metres from the stationary entity (20 metres as defined for the NEAR LOD, plus 4 metres for its hysteresis). If no <hyst> parameter were specified, the change would happen at 30 metres (since hysteresis would then default to 10 metres).
- The change of LOD for the moving entity from MEDIUM to NEAR occurs at 20 metres from the stationary entity (since hysteresis does not affect moving to a higher LOD).

Chapter 5. User Data Object Linking With UDO_REF Properties

There is a special property type, `UDO_REF`, that can be used in both entities and user data objects. This property type makes it possible to create a connection between an entity and a user data object, or between two user data objects. This property type is a key feature of user data objects, as it allows the creation of complex graphs made up of different types of user data objects and entities that can be used by the entity scripts as desired. A `UDO_REF` property is nothing more than a reference to a user data object. When an entity or a user data object with a `UDO_REF` property is loaded, the user data object referenced by the `UDO_REF` property could exist in an unloaded state if the user data object referenced hasn't been loaded yet. In this case, the script will only be able to get the user data object's unique identification number through the `guid` attribute. Once the referenced user data object is loaded, all it's attributes and properties can be accessed.

The most important example of this property type is in the PatrolNode user data object. The old patrol path system, including the old `PATROL_PATH` property type, have been deprecated. Patrol functionality is now achieved with the `PatrolNode` user data object, which can be linked to other `PatrolNode` objects through an array of `UDO_REF` properties. Entities that wish to patrol through a graph of `PatrolNode` objects just need have a `UDO_REF` property that links to a `PatrolNode.`

Chapter 6. Methods

Methods allow events to be propagated, both between different execution contexts of an entity (*i.e.*, cell, base, client), as well as between different entities. BigWorld separates entity methods into categories based on which execution context they will be executed within.

In general, methods should not be used for propagating states. The use of properties is recommended for this purpose. For example, a player holding a gun should be a property, while a player shooting should be a method.

The categories of methods are:

Category	Runs on	Common uses
`<BaseMethods>`	BaseApp	Updates properties on the base. Serves as a root point to propagate messages to related things.
`<CellMethods>`	CellApp	Notifies the cell of changes in response to player interaction. Allows communication between nearby entities.
`<ClientMethods>`	Clients	Notifies the client of events, so that the player can see them. Implicit `set_<property_name>` methods need not be declared[a].

[a] For details, see "Implicit `set_<property_name>` Methods" on page 45

The grammar for method declaration is described below:

```
<[ClientMethods|CellMethods|BaseMethods]>

  <method_name>
    <Exposed/>
    <Arg> data_type </Arg>
   </method_name>

</[ClientMethods|CellMethods|BaseMethods]>
```

`<res>/scripts/entity_defs/<entity>.def` - Method declaration syntax

6.1. Basic Method Specification

All methods in all categories have some fundamental common characteristics. They are declared in the relevant section in the file `<res>/scripts/entity_defs/<entity>.def`, with an XML tag per method.

The method's arguments are also defined in the file, and its types are specified in the same way as property types. For more details, see "Property Types" on page 17 .

In order to declare a method called `yell` on the cell, which receives a string argument, we would have the lines below:

```
<root>
  ...
  <CellMethods>
    <yell>
      <Arg> STRING </Arg> <!-- phrase to exclaim -->
    </yell>
  </CellMethods>
  ...
```

```
</root>
```

<res>/scripts/entity_defs/<entity>.def - Declaration of cell method yell

By convention, the meaning of each argument is written next to it as an XML comment.

Once the method is declared, it also needs to be declared in the appropriate Python implementation file. Each context of execution (cell, base, and client) has a folder containing scripts for each entity.

In our example, the method was added to the section `<CellMethods>`, and therefore will be executed on the cell entity.

The cell script for this entity, named `<res>/scripts/cell/<entity>.py`, will need to define the `yell` method, as illustrated below:

```
import BigWorld
...
class entity(BigWorld.Entity):

  def __init__(self):
    BigWorld.Entity.__init__(self)

  def yell(self, phrase):
    # insert code to implement yell here
    return
```

<res>/scripts/cell/<entity>.py - Definition of cell method yell

6.2. Intra-Entity Communication

Different execution contexts of an entity communicate with each other by calling methods on the other execution contexts. These are exposed as special properties of the entity.

As a quick reference, the available objects are described below:

- **`allClients` - Available on: Cell**

  When/how to use: To call a client method on all client instances of this entity.

  Example: `self.allClients.someMethod()`

- **`base` - Available on: Cell, Client**

  When/how to use: To call a base method of this entity. Calls to this object are executed on the base script. The client cannot directly call methods on the base of other entities.

  Example: `self.base.someMethod()`

- **`cell` - Available on: Base, Client**

  When/how to use: To call a cell method of this entity. Calls to this object are executed on the cell script. All client instances can access their cell object (when the entity exists on the cell).

  Example: `self.cell.someMethod()`

- **`otherClients` - Available on: Cell**

  When/how to use: To call a client method on all client instances of this entity, except on its own.

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Example: `self.otherClients.someMethod()`

- **`ownClient` - Available on: Cell, Base**

  When/how to use: To call a client method only on this entity's client. This object calls the method only on the entity on the client application that is 'playing' as this entity, not on other client applications that can see this entity.

  Example: `self.ownClient.someMethod()`

The methods of a nearby entity can be called from the client directly on the cell part of that entity.

BigWorld automatically exposes these objects to the relevant script classes.

What this means is that it is possible for any script that is part of an entity (cell, base or client part) to call other scripts that are part of the same entity. The definition file (`<res>/scripts/entity_defs/<entity>.def`) describes which methods are exposed to different execution contexts.

6.3. Sending Auxiliary Data to the Client Via Proxy

Auxiliary data can be streamed to the client via the proxy, without affecting the normal game traffic. Proxy data is opportunistically streamed to the client when bandwidth is available.

All data types in the proxy data are user-defined, since BigWorld does not have any internal uses for it.

Data is added to a proxy via method `addProxyData`:

```
id = Proxy.addProxyData( id, data )
```

Where the parameters are:

- ***`id`***

  16-bit ID of the data. If `-1` is received, then the next ID in sequence that is not currently in use is selected. The caller of this method is responsible for the management of this parameter. The same ID value used by the method is returned to the caller.

- ***`data`***

  Data to be sent to the attached client. Must be in string format.

Once the client has received the entire data string, the virtual method `onProxyData` in the `ServerMessageHandler` interface is invoked.

6.4. Exposed Methods - Client-to-Server Communication

Because MMOGs operate over the Internet, and in order to stop players cheating, server methods (those on the cell or the base) are not automatically allowed to be called by the client.

In order to make a server method callable from the client (so that the world can provide interactivity), its declaration has to include the tag `<Exposed/>`, as illustrated below:

```
<root>
  ...
  <CellMethods>
    <yell>
```

```
      <Exposed/>
      <Arg> STRING </Arg> <!-- phrase to exclaim -->
    </yell>
  </CellMethods>
  ...
</root>
```

<res>/scripts/entity_defs/<entity>.def - Declaration of the exposed method

The tag <Exposed/> accomplishes two things:

- It makes the method available to clients.
- On the cell, it acts as an <Arg> tag that is automatically filled in with the entity ID of the client calling it.

Client instances actually call the method with one argument less than are received by the cell entity, which prevents 'entity-faking' outside the safe server environment. The entity ID needs to be passed as an argument when calling exposed methods from the server components.

The definition of the method on the cell must be extended to take this parameter, as illustrated below:

```
import BigWorld
class EntityName(BigWorld.Entity):

  def __init__(self):
    BigWorld.Entity.init(self)

  def yell(self, sourceEntityID, phrase):
    # insert code to implement yell here
    # if desired, check that self.id == sourceEntityID before proceeding
    return
```

<res>/scripts/cell/<entity>.py - Definition of cell method yell

On the client, the method yell can be called with the code below:

```
self.cell.yell( "BigWorld message test" )
```

Example of a client calling a cell method **yell**

If the cell method yell implements the check of sourceEntityID against self.id, only its client will be able to call it. Others clients will not be able to execute it.

There might be occasions where the method might run with a different sourceEntityID. For example, for a method called shakeHand, it is a good idea to check that the source entity is within a couple of metres away from the self entity before proceeding (and maybe that neither is dead).

6.4.1. Security Considerations of Exposed Methods

Script writers should be aware that the arguments of any exposed method need to be heavily scrutinised on the server side before being operated on.

The underlying C++ code that handles the passing of arguments ensures that the method will be invoked on the server side only if:

- The right number of arguments is being passed.

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- The arguments have the expected type.

Beyond that, however, the underlying architecture cannot provide any further constraints on the values that clients may pass to method calls on the server.

For example, integers may take any valid 32-bit value, strings and arrays may be of any length, …. It is up to the script writer to ensure that the arguments to an exposed method have values that make sense in the context of that method.

You should carefully inspect the value of any arguments to an exposed method before using them.

It is never safe to trust arbitrary Python objects from the client as passed in through PYTHON parameters to exposed method invocations. A WARNING log message is emitted at startup by any component that parses the entity definitions if an exposed method has parameter of type PYTHON. The safer alternative is to use some other data type that is more concretely defined, for example the FIXED_DICT data type, and validate each known element.

6.5. Implicit set_<property_name> Methods

When the server updates a property with distribution flag [1] ALL_CLIENTS, OTHER_CLIENTS or OWN_CLIENT, an implicit method called set_<property_name> is called on the client.

This method should not need be declared in the section <ClientMethods> of the definition file as it is automatically provided by BigWorld.

All implicitly defined set_property_name methods have one argument which receives the old value of the property when the method is called. For example:

```
class Seat( BigWorld.Entity ):
    ...
 def set_seatType( self, oldType = None ):
  ...
```

<res>/scripts/client/Seat.py - Example of an implicit set_seatType for the Seat entity.

6.6. LOD on Methods

Like properties, some methods need to be broadcast only to nearby entities.

For example, even though an entity may be visible at an AoI distance (500 metres), it seems unlikely that players will be able to tell the difference between a smiling and a non-smiling entity.

To reflect his, the smile method's level of detail, can be declared as illustrated below:

```
<root>
  ...
  <ClientMethods>
    ...
    <smile>
      ...
      <DetailDistance> 30 </DetailDistance>
    </smile>
    ...
  </ClientMethods>
  ...
```

[1] For details on property's distribution flags, see “Data Distribution” on page 26

```
</root>
```

<*res*>/scripts/cell/<*entity*>.py - Declaration of client method `smile`

The specification of the LOD for a method is far simpler than it is for a property. This is because a non-broadcast property change might have to be sent later if the LOD increases, while a non-broadcast method in the same scenario will not have to.

Consequently, the method just needs to declare a tag `<DetailDistance>` inline, and when it is called on exposed objects `allClients` or `otherClients`, it is broadcast only to clients within the specified distance around the entity.

6.7. Inter-Entity Communication

Once the entities have methods assigned to them, it becomes useful to be able to call methods on other entities.

If you have an object `ent` as a Python script representation of another entity, then you can call `ent.someMethod`() to call that method on `ent`. This assumes that `someMethod`() runs on the same execution context you are in. For example, if you are on the cell, then `ent.someMethod`() must be defined and provided by the entity type of `ent`.

If you are on the cell, you can call a method on the base, with the code below:

```
ent.base.otherMethod()
```

This means that once you are able to obtain an entity object, there is a plethora of options for invoking methods on different execution contexts of different entity instances. For more details, see “Intra-Entity Communication” on page 42 .

But to achieve this, first it is necessary to retrieve the object for another entity. The mechanism for that is described in the next sub-section

6.7.1. Entity IDs

In order to uniquely identify every object in the game universe, BigWorld assigns a unique number to every entity. This is referred to as the entity ID.

In the `BigWorld` Python module (which is imported at the start of most scripts), there is an object which maps entity IDs to the corresponding entity object. This object has the same interface as a Python dictionary, and is called `BigWorld.entities`.

Given an entity id `entityID`, its entity object can be retrieved with the code below:

```
ent = BigWorld.entities[ entityID ]
```

Retrieval of entity object using its ID

One should be very careful with entity IDs, and always check for the existence of the corresponding entity before assuming that it is safe to use it. `BigWorld.entities` throws an exception if the entity looked up does not exist.

Each execution context has a version of the `BigWorld.entities` object with different entities in it.

`BigWorld.entities` contains the entities that are relevant to the execution context in which it is located, as listed below:

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Execution context	Entities listed in `BigWorld.entities`
Cell	Real and ghosted entities located on all cells managed by this cell's CellApp.
Base	Entities located on this base's BaseApp [a].
Client	Entities in the client's AoI.

[a] For sending messages to bases on other BaseApps, see "Mailboxes" on page 47

Entity IDs can be obtained in various ways:

1. From exposed methods (client sends entity ID as argument).
2. From the entity object's `id` property.

   You can pass the object's ID from one execution context to another (*e.g.*, from the client to the cell), so that the other context can obtain the corresponding object. You can also use this property to obtain the ID of a newly created entity.
3. From various utility methods that one can use to find entity references.

   One of these methods is `entitiesInRange`[2]. This method is defined for every cell entity, and returns all entity objects located within a certain distance from the calling entity. The resulting output can be queried again for more specific search results.

   For example, to find all the `Guard` entities within 100 metres of the current entity, you could have the code below:

```
def findGuards():
  output = []
  for entity in self.entitiesInRange( 100 ):
    if entity.__class__.__name__ == "Guard":
      output += [entity]
  return output
```

`<res>/scripts/cell/<entity>.py` - Obtaining ID of surrounding entities

   Care should be taken when using this approach for entity discovery as it is a linear search, and hence does not scale well. Specifically to be avoided are searches over large entity sets that could be obtained from a search of large distances, or from using the complete set of entities in `BigWorld.entities`. For a small distance however, one would not expect large numbers of objects (although this depends on the game).

6.8. Mailboxes

Mailboxes are used to communicate to entities that are remote, *i.e.*, not on the current process.

Entities can only access other entities that are running in the same execution context[3], however it is frequently useful to be able to send a message to entities in other execution contexts. For example, an entity may wish to send a message to all members of a chat channel, but the channel might not have all its members located on the same BaseApp as the executing entity.

Mailboxes are used to implement the following properties of an entity:

- `self.cell`
- `self.base`

[3] For more details, see "Inter-Entity Communication" on page 46

- `self.ownClient`

These properties allow you to reference objects located on different processes, and can be sent like any other value, using method calls, and the `MAILBOX` data type.

You can use the `MAILBOX` like a normal entity reference, and call methods declared in the entity's definition file on other entities on other processes.

Considering that an entity *B* (referenced in the following example as `anotherEntity`) has a method `heyThere` which takes one argument of type `MAILBOX`, an entity *A* can pass its base mailbox to entity *B* from the cell, as in the example below:

```
anotherEntity.heyThere( self.base )
```

<res>/scripts/cell/<original_entity>.py - Passing base mailbox from cell

On the receiving entity *B* (referenced in the example as `anotherEntity`), the calling entities (entity *A*) base mailbox (as received via the method argument) can be used to call a method `someMethod` on entity *A*. For example:

```
def heyThere( self, originalEntity ):
  originalEntity.someMethod()
```

<res>/scripts/cell/<another_entity>.py - Receiving base mailbox

It is also possible to store mailboxes in a class as properties. However this is only useful for base entity mailboxes, since they will not change address as the entity moves around the space.

Cell entity mailboxes should not be stored, because they can change as the entity moves between cells. It is possible to pass cell entity mailboxes to another entity for once-off use, since they are guaranteed to be usable for the time it takes to call a method and have it respond (*i.e.*, up to approximately 1 second).

Using mailboxes, it is also possible to call methods within a different execution context to that of the mailbox being called. For example, using a base mailbox of an entity (`baseMB` in the following code), it is possible to call a cell method of the base entity as follows:

```
baseMB.cell.cellMethod()
```

Calling a cell method of another entity through its base mailbox

The call is sent to the base entity first, which then calls the cell method from where the base entity resides. Though it is more convenient than calling a base method that in turn calls the cell method, it still takes two hops to call the cell entity.

Available usages are:

- `baseMB.cell`
- `baseMB.ownClient`
- `cellMB.base`
- `cellMB.ownClient`

These are in fact instances of MailBoxes, and can be passed as method arguments. However, the same restriction applies to `cellMB.base` and `cellMB.client` as to cell mailboxes - they can change as an entity moves around, and therefore should not be stored for later use.

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Note that both `baseMB.ownClient` and `cellMB.ownClient` refer to their own client only. There are no shortcut calls to `otherClients` and `allClients`.

A convenient way to obtain other entities' mailboxes is by using the methods `BigWorld.lookUpBaseByDBID` and `BigWorld.lookUpBaseByName` on the BaseApp. For more details, see the BaseApp Python API documentation's entry **Main Page → BigWorld (Module) → Member Functions**.

6.9. Method Execution Context

All entity method calls across physical machines are asynchronous. For example, if you execute `self.cell.cellMethod()` or `self.client.clientMethod()` on a base entity, the call returns immediately without any value. The actual method execution takes place on the machine where the cell or client part of the entity resides.

To inform the calling entity of the execution result you will have to call a function from within the method.

The example below describes the client entity of class `Avatar` initiating a sequence of actions to open a door, executing the following steps:

1. The client method `openDoor` of class `Avatar` calls its cell method `openDoor`.
2. That method then calls the cell method `unlock` of class `Door`, passing `self` as an argument. This way, `Door` receives a mailbox of the cell entity `Avatar`, which is later used (with exposed object client) to call the appropriate cell method on `Avatar`.
3. That method then checks the keycard, and using the cell mailbox (`sourceEntity`), makes a call directly to the appropriate client method of class `Avatar` (in this example, we assume it was successful).

- **The client entity of the `Avatar` class:**

```
class Avatar( ):
  ...
  def openDoor( self, doorID ):
    # Call the cell method to open the door
    self.cell.openDoor( doorID )
  ...
  def doorOpenFailed( self, doorID, keycard ):
    # Animation shows the Avatar scratching his head
  ...
  def doorOpenSucceeded( self, doorID, keycard ):
    # Animation shows the door with corresponding doorID opening
  ...
```

<res>/scripts/client/Avatar.py - Definition of door methods

- **The cell entity of the `Avatar` class:**

```
class Avatar( ):
  ...
  def openDoor( self, doorID ):
    # locate the door
    door = self.locateTheDoor( doorID )
    keycard = self.getKeycardFromInventory()
    door.unlock( self, keycard )
   ...
```

<res>/scripts/cell/Avatar.py - Definition of methodopenDoor

- **The cell entity of the `Door` class:**

```
class Door( BigWorld.Entity ):
  ...
  def unlock( self, sourceEntity, keycard ):
  # check source is close enough
  # check keycard is good
  if not self.isGoodKeycard( keycard ):
    sourceEntity.client.doorOpenFailed( self.id, keycard )
  else:
    self.isOpen = True
    sourceEntity.client.doorOpenSucceeded( self.id, keycard )
  ...
```

<*res*>/scripts/cell/Door.py - Definition of `methodunlock`

The same callback technique is used to return values from a called method.

The example below describes the client entity of class `Avatar` initiating a sequence of actions to inquire about an item's description based on its inventory index, executing the following steps:

1. The client method `investigateInventory` of class `Avatar` calls its base method `itemDescriptionRequest`.
2. That method then calls its client method `itemDescriptionReply`.
3. That method then displays the item's description.

- **The client entity of the `Avatar` class:**

```
class Avatar( ):
  ...
  def investigateInventory( self, indexInInventory ):
    # first get the details from the server
    self.base.itemDescriptionRequest( indexInInventory )
    # maybe have a timeout in case server doesn't reply
  ...
  def itemDescriptionReply( self, indexInInventory, desc ):
    # call the callback
    if desc == []:
      GUI.addAlert( "No such item" + str(indexInInventory) )
      return
    GUI.displayItemWindow( indexInInventory, desc )
  ...
```

Example <*res*>/scripts/client/Avatar.py - Definition of inventory methods

- **The base entity of the `Avatar` class:**

```
class Avatar( ):
  ...
  def itemDescriptionRequest( self, indexInInventory ):
    try:
      desc = self.generateDescription( indexInInventory )
    except:
      desc = []    # in case no such index
    self.client.itemDescriptionReply( indexInInventory, desc )
  ...
```


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Example <*res*>/scripts/cell/Avatar.py - Definition of itemDescriptionRequest

For those entities residing in the same process, the method calls take place synchronously. However, since there is no guarantee that the calling entities and the called ones will always be in the same process, it is better to adopt the callback solution.

A special case is an entity method that is not defined in the entity's definition file (<*res*>/scripts/entity_defs/<*entity*>.def - For details, see “The Entity Definition File” on page 12). In this case, the method is always executed synchronously, and is only executed in the process of the caller. For example, a method call on a ghosted entity normally will be delegated to the real one. However, if this method is not defined in the entity's definition file, it will be treated as a usual Python method, and run locally.

This mechanism does save a bit of network traffic between server components, and can return a result immediately to the caller, but it is also limited in that it can only access the read-only ghosted properties. Trying to access non-ghosted properties or to write read-only properties would result in unexpected errors. Unless carefully planned, one should not take advantage of this feature.

Chapter 7. Inheritance in BigWorld

Class-based inheritance is a useful design technique in object-orientated software, and is implemented in most object-orientated languages.

BigWorld uses three separate classes (for the cell, base, and client entity parts) to implement an entity, and a definition file (`<res>/scripts/entity_defs/<entity>.def`) to tie them all together. As such, there are a variety of ways that entities, or parts of entities, may use inheritance in their specification and implementation.

There are three different ways to declare inheritance relationships in BigWorld, all fulfilling different needs.

7.1. Python Class Inheritance

The Python language allows classes to be derived from each other.

For example, to define a class `B`, derived from `A`, and methods for each of them, you can have the code below:

```
class A:
  def f( self ):
    print "A.f was called"

class B( A ):
  def g( self ):
    print "B.g was called"
```

Declaring Python class A and its derived class B

Then suppose you have a program with the code below:

```
x = B()
x.f()
x.g()
```

Program using Python class inheritance

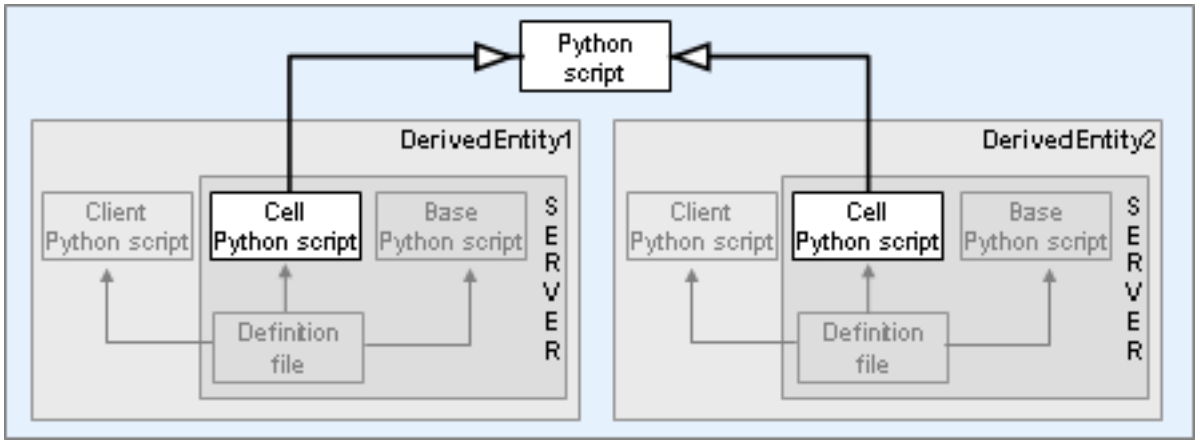
The output of this program will be as illustrated below:

```
A.f was called
B.g was called
```

Example program output

When used in entities, this form of inheritance allows the sharing of common implementation details between entity types. Multiple inheritance is allowed, so that you can use many Python classes to help implement disparate features in some entities.

This concept is illustrated in the diagram and code fragments below:



Python class inheritance

The code fragments below show how the Python class `CommonBase` could be used in an entity `DerivedEntity`[1]

1. If a base class' cell script (`<res>/scripts/cell/CommonBase.py`) is defined as below:

```
# note that this class is not derived from BigWorld.Entity
# so it is just an ordinary Python class
class CommonBase:
  ...
  def readyForAction( self ):
    # implement method's logic
    return True
  ...
```

2. If a derived entity's cell script (`<res>/scripts/cell/DerivedEntity1.py`) is defined as below:

```
import BigWorld
from common import CommonBase
...
# derive from CommonBase, so you can use the method readyForAction
class DerivedEntity1( BigWorld.Entity, CommonBase ):
  ...
  def __init__( self ):
    BigWorld.Entity.__init__( self )
    CommonBase.__init__( self )
  ...
  def someAction( self ):
    if self.readyForAction():
      print "action performed"
  ...
```

3. Then you can call methods from the base class, as illustrated below:

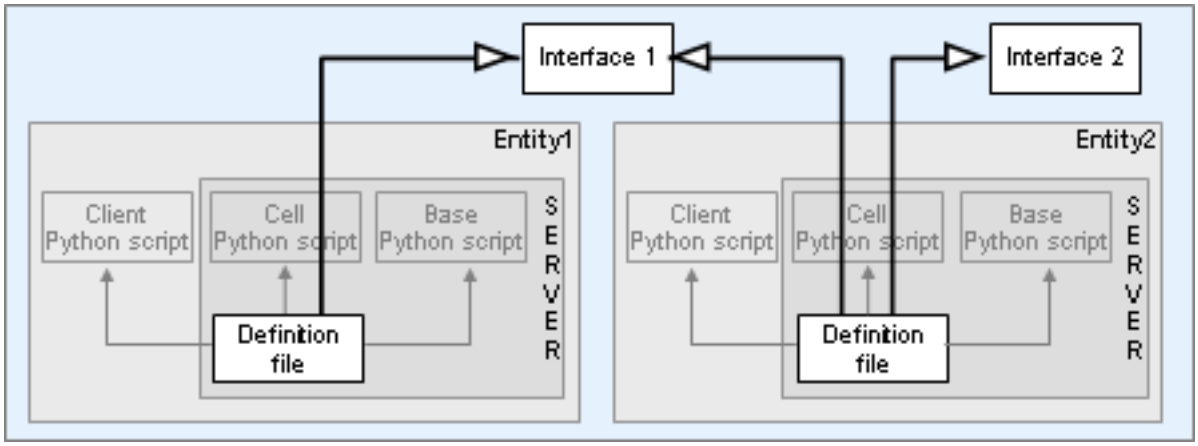
```
DerivedEntity1.readyForAction()
```

[1] Although this example is implemented on the cell, this technique is also useful for base and client scripts.

7.2. Entity Interfaces

BigWorld also supports inheritance in a form similar to Java's interface system. There can be a folder `<res>/scripts/defs/interfaces` that can be used to declare common parts of entities. This allows the definition in one place of often-used declarations.

This concept is illustrated below:



Python entity interfaces

The format of entity interface definition files is similar to the format of entity definition files, except that interface definition files do not have the section `<Parent>`. For more details on entity definition files, see "The Entity Definition File" on page 12 .

The outline of an interface definition file is described below (all sections are optional):

```
<root>

  <Implements>
    <!-- interface references -->
  </Implements>

  <Properties> 1
    <!-- properties -->
  </Properties>

  <ClientMethods> 2
    <!-- client methods -->
  </ClientMethods>

  <CellMethods> 3
    <!-- cell methods -->
  </CellMethods>

  <BaseMethods> 4
    <!-- base methods -->
  </BaseMethods>

  <LoDLevels> 5
    <!-- levels of detail -->
  </LODLevels>

</root>
```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<res>/scripts/entity_defs/interfaces/<entity>.def - Minimal entity definition file

1 For details, see *Properties* on page 17 .
2 For details, see *Methods* on page 41 .
3 For details, see *Methods* on page 41 .
4 For details, see *Methods* on page 41 .
5 For details, see "LOD (Level of Detail) on Properties" on page 37 .

Unlike entities, entity interfaces do not need to have associated Python implementation files, although this can be a good idea.

The code fragments below illustrate the result of using an interface in an entity definition file:

1. If an entity is defined implementing an interface (`<res>/scripts/entity_defs/someEntity.def`), as below:

```
<!-- someEntity -->
<root>
  ...
  <Implements>
    <Interface> someInterface </Interface>
  </Implements>
  ...
</root>
```

2. And if the implemented interface is defined (`<res>/scripts/entity_defs/interfaces/someInterface.def`) as below:

```
<!-- someInterface -->
<root>
  <Properties>
    <name>
      <Type>  STRING       </Type>
      <Flags> ALL_CLIENTS  </Flags>
    </name>
  </Properties>
</root>
```

3. Then conceptually, the resulting entity definition is as defined as below:

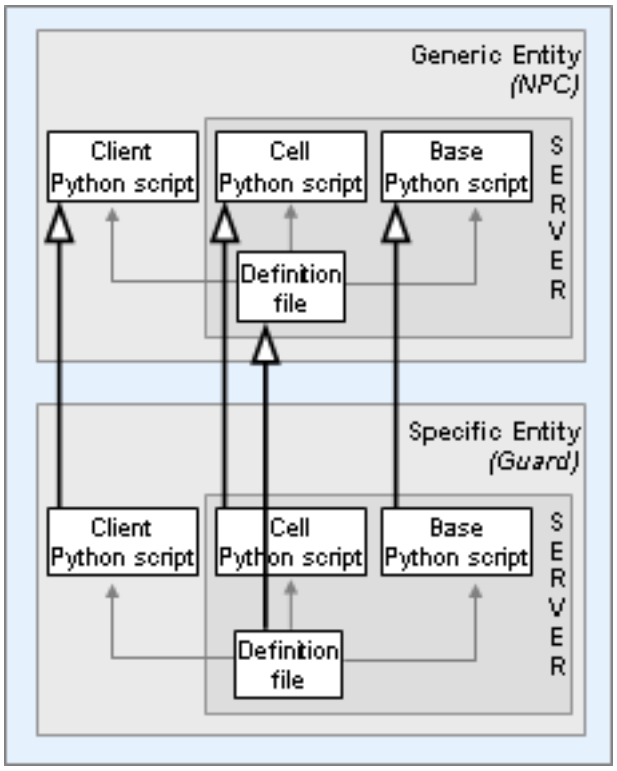
```
<!-- someEntity -->
<root>
  ...
  <Properties>
    <name>
      <Type>  STRING       </Type>
      <Flags> ALL_CLIENTS  </Flags>
    </name>
  </Properties>
  ...
</root>
```

A property from an interface can be overridden if the description needs to be changed. In this case, the entire property description is replaced with the new one, so all appropriate fields need to be specified.

7.3. Entity Parents

It is often possible to define an entity that provides functionality common to other entity types as a single base entity. For example, a collection of NPCs may share most of their implementation, but need some specific tuning to turn them into a guard or a shopkeeper.

This concept is illustrated below:



Python entity parents

The code fragments below demonstrate this form of inheritance.

1. Define the base entity `GenericEntity` (`<res>/scripts/entity_defs/GenericEntity.def`):

```
<!-- GenericEntity -->
<root>
  <!-- common properties and methods -->
</root>
```

2. Define `GenericEntity`'s base script:

```
import BigWorld

class GenericEntity( BigWorld.Base ):
  ...
  def __init__( self ):
    BigWorld.Base.__init__( self )
  ...
```

3. Define `GenericEntity`'s cell script:

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```
import BigWorld

class GenericEntity( BigWorld.Entity ):
  ...
  def __init__( self ):
    BigWorld.Entity.__init__( self )
  ...
```

4. Define derived entity `SpecificEntity`:

```
<!-- SpecificEntity -->
<root>
  <!-- inheritance is defined in this tag -->
  <Parent> GenericEntity </Parent>

  <!-- add more properties and methods here -->
</root>
```

5. Define `SpecificEntity`'s base script:

```
import BigWorld
import GenericEntity

class SpecificEntity( GenericEntity.GenericEntity ):
  ...
  def __init__( self ):
    GenericEntity.GenericEntity.__init__( self )
 ...
```

6. Define `SpecificEntity`'s cell script:

```
import BigWorld
import GenericEntity

class SpecificEntity( GenericEntity.GenericEntity ):
  ...
  def __init__( self ):
    GenericEntity.GenericEntity.__init__( self )
  ...
```

7.4. Client Entity Reuse

There may be times when an entity type only needs to be specialised on the server. Using the optional section `<ClientName>` in a `.def` file allows a different (usually parent) entity type to be used for the client entity.

For example, if `NPC` is derived from `Avatar`, and `NPC` contains additional properties that the client does not need to access, `NPC` objects can be sent to clients as `Avatar` objects. This means that the client does not need a specific script to handle `NPC`s.

7.5. User Data Object Interfaces and Parents

The inheritance of interfaces and parents described for entities also apply to User Data Objects. Due to the similarity of User Data Objects to regular Entities, for further details, please refer to sections “Entity Interfaces” on page 54 and “Entity Parents” on page 56

For an example of inheritance in User Data Objects see `<res>/scripts/user_data_object_defs/testItem.def` and `<res>/scripts/user_data_object_defs/testParent.def`.

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Chapter 8. Entity Instantiation and Destruction

Due to the way that BigWorld entities must be set up and linked to each other, they must be instantiated differently to how other objects are instantiated in Python. Similarly, because the parts must be unlinked at destruction time, there are special ways of accomplishing this.

As mentioned in section "The Script Files" on page 13 , an entity can have a part located on the cell (in both real and ghost forms), a part on the base, and another on clients that have the entity in their AoI. Different entity types may support their instances being only on one, two, or all three of these. Also, it is possible for instances of entity types to have less parts than their type supports.

Most commonly, the base part of an entity is created first and then, if appropriate, its cell part. There are a number of reasons for this.

- The base entity can be created directly from the database, while the cell entity cannot.
- The base entity can create its cell part, but the reverse is not true.
- The cell entity needs an associated base entity to be fault-tolerant.
- The cell entity needs an associated base entity to write itself to the database.

For entity types that have base and cell parts, the base part is always created before the cell part, and destroyed after it. It is also possible to create a cell entity that does not have a base part.

8.1. Entity Instantiation on the BaseApp

The base entity can be created in the following ways:

- Directly from script, using the methods `BigWorld.createBaseAnywhere` [1], `BigWorld.createBaseLocally`, or `BigWorld.createBaseRemotely`
- From the database, using the methods `BigWorld.createBaseFromDBID` or `BigWorld.createBaseFromDB`.

For more details on instantiating entities from the data stored in the database, see *The Database Layer* on page 66 .

The method `BigWorld.createBaseAnywhere` can specify both the base and cell entity properties, and has the following signature:

```
def createBaseAnywhere( entityTypeName, *args, **kwargs ):
```

Method `BigWorld.createBaseAnywhere`'s signature

The parameter *`entityTypeName`* is a string containing the name of the entity type to instantiate. For example, to instantiate an entity `ExampleEntity`, this parameter would be `"ExampleEntity"`.

In its simplest form, it creates the entity with all default values, and is invoked as in the example below:

```
newEntity = BigWorld.createBaseAnywhere( "ExampleEntity" )
```

Example of method `BigWorld.createBaseAnywhere`

This method can optionally take a list of other parameters that are searched to create base and cell entity values. These parameters can be:

- Keyword arguments
- Dictionaries
- `ResMgr.DataSection`

The keyword arguments are searched first, then the dictionaries, and finally the DataSection. If a value is not found for any of the entity's properties, the default value for that property / data type is assigned.

Keyword arguments and dictionary values not found in the entity's definition are set as base entity properties.

8.2. Cell Entity Creation From BaseApp

The method `BigWorld.createBaseAnywhere` creates only the base representation of the entity. If a cell entity is required, it is the base entity's duty to instantiate its associated cell entity.

To create the associated cell entity, the following methods are used:

- `Base.createCellEntity`
- `Base.createInNewSpace`
- `Base.createInDefaultSpace`

These methods read the base entity's special variable `Base.cellData` (which is initialised with the cell entity's data when the base entity is created) to get the initialisation values for the cell entity. If the entity type does not support a cell entity, the base entity will not have `cellData`.

The variable `cellData` is behaves like a dictionary containing all cell properties defined in the entity's definition file (`<res>/scripts/entity_defs/<entity>.def`).

It also has three additional members:

- **`position`** - Sequence of three floats (x, y, z), or a Vector3 with position to create the new entity at.
- **`direction`** - Sequence of three floats (roll, pitch and yaw) with direction for the new cell entity.
- **`spaceID`** - ID of the space for the cell entity to be created in, if space is not specified in a different way.

Once the cell entity is successfully created, the following steps take place:

1. The variable `cellData` is deleted.
2. A variable called `cell` is created, with the mailbox of the cell entity.
3. The callback `Base.onGetCell` is invoked.

8.2.1. Creation Near an Existing Cell Entity

The diagram below illustrates the creation of the cell entity using the method `Base.createCellEntity` of the `BigWorld` module. This method cannot be used when the cell entity has already been created.

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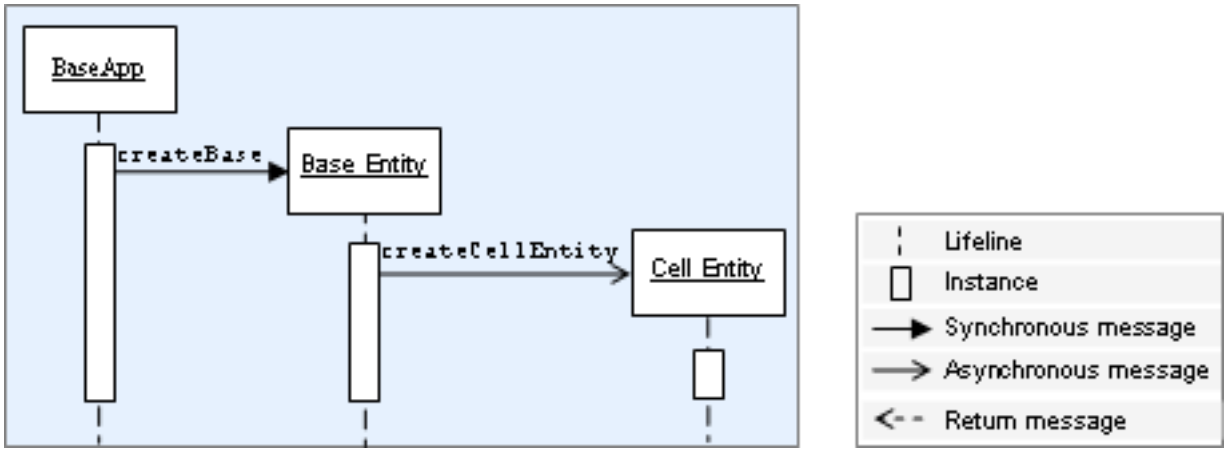


Creation of the cell entity using the method `createCellEntity` of `BigWorld.Base`.

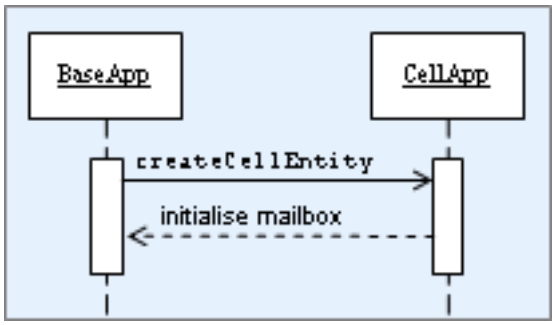
The declaration of method `createCellEntity` in Python would look like this[2]:

```
class Base:
  ...
  def createCellEntity( self, mailbox = None ):
    ...
```

<res>`/scripts/base/Base.py` - Declaration of method `createCellEntity`

The parameter `mailbox` is a cell entity mailbox. The new cell entity is created in the same space and cell as the mailbox references (if `mailbox` is not `None`). Ideally, the two entities are close, as this increases the likelihood of the entity starting on the correct cell.

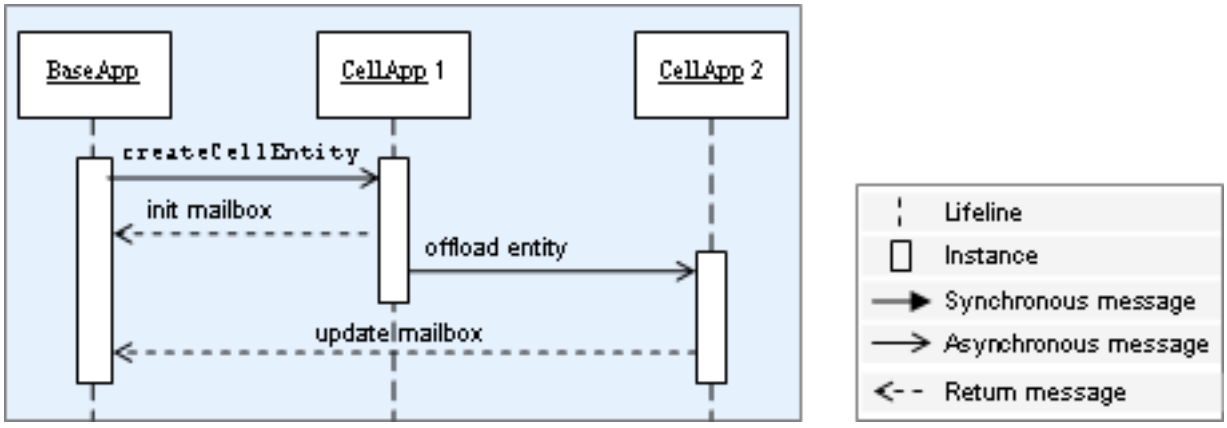
The diagram below shows the flow of communications if the entity is created on the correct cell:



Flow of communication when cell entity is created on correct cell.

The diagram below shows the flow of communications if the entity is created on an incorrect cell:

[2]The method `createCellEntity` is implemented in C++ - the example declares it in Python just for explanation purposes.



Flow of communication when cell entity is created on an incorrect cell.

8.2.2. Creation in a Numbered Space

It is also possible to create the cell entity by having an appropriate value for `spaceID` in the property `cellData`. This should be avoided, as it requires the request to go via the CellAppMgr, which can cause a bottleneck.

Once the cell entity has been created, the notification method `onGetCell` is called on the base entity. This is the signal that it is now safe to start using the mailbox to the cell entity `self.cell`.

For entity `someEntity`, the method `onGetCell` can be defined as illustrated below:

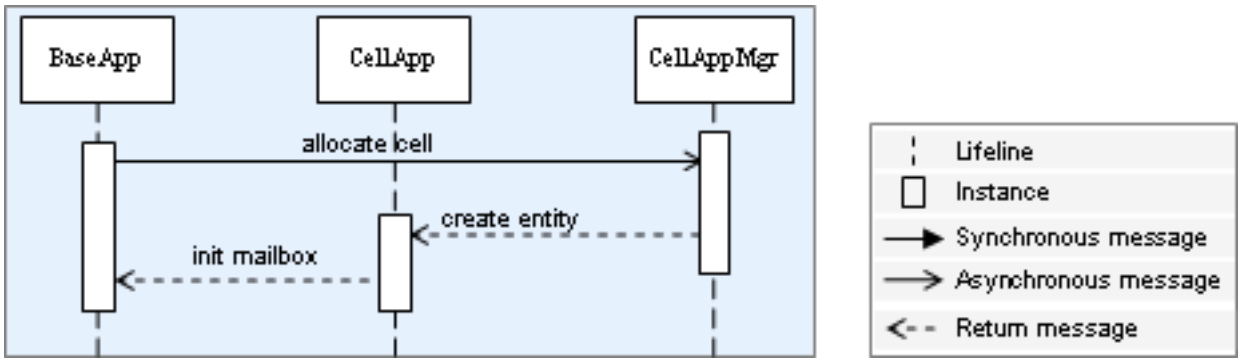
```
import BigWorld

class someEntity( BigWorld.Base ):
  ...
  def onGetCell( self ):
    # this method was called, that means cell entity has been created.
  ...
```

<res>`/scripts/base/someEntity.py` - Definition of method `onGetCell`

8.2.3. Creation in a New Space

The method `Base.createInNewSpace` dispatches a request to the CellAppMgr to create a new space, and the entity on it.

The resulting message trace is illustrated below:



Flow of communication when creating cell entity on a new space.

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8.2.4. Creation in Default Space

The method `Base.createInDefaultSpace` is similar to method `Base.createInNewSpace`, except that a new space is not created.

This is only available if flag `<useDefaultSpace>` is set to `true` in the configuration file `<res>/server/bw.xml`.

8.3. Entity Destruction

The base entity is always created before the cell entity and is destroyed after it.

The sequence of events ensued by the destruction of a cell entity is described below:

Step	Base	Cell
1	Calls method `destroyCellEntity`.	Calls method `destroy`.
2		Has method `onDestroy` automatically called.
3	Has method `onLoseCell` automatically called. If base is to be destroyed, this is a good place to call method destroy.	
4	`cell` property is lost[a].	
5	`cellData` property is restored, with values it had when destroyed[b].	

[a] For details on this property, see “Cell Entity Creation From BaseApp” on page 60 .

[b] For details on this property, see “Cell Entity Creation From BaseApp” on page 60 .

The method `Base.destroy` has two Boolean keyword arguments:

- ***`deleteFromDB`*** - The default value is `false`.
- ***`writeToDB`*** - The default value is `true` if the entity has previously been written to the database.

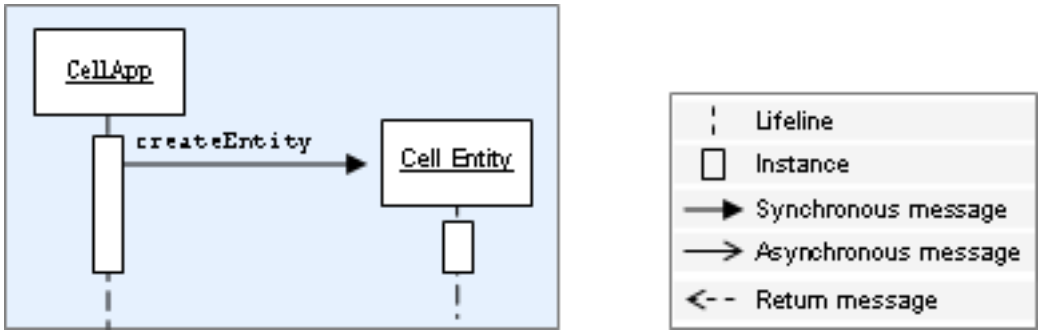
8.4. Entity Instantiation From The CellApp

When creating a cell entity, it can be created either with its base counterpart or not. The following sub-sections describe both approaches.

8.4.1. Instantiation With No Base Counterpart

The method `BigWorld.createEntity` can be called to create a cell entity with no associated base entity.

This scenario is illustrated below:



Creation of cell entity without base counterpart.

The method `BigWorld.createEntity` has the following signature:

```
def createEntity( entityTypeName, spaceID, position, direction, properties ):
```

Method `BigWorld.createEntity`'s signature.

For details on the parameters for this method, see the CellApp Python API documentation's entry **Main Page → Cell → BigWorld → Function → `createEntity`**.

8.4.2. Instantiation With Base Counterpart

The method `BigWorld.createEntityOnBase` allows the CellApp to create base entities. It has the following signature:

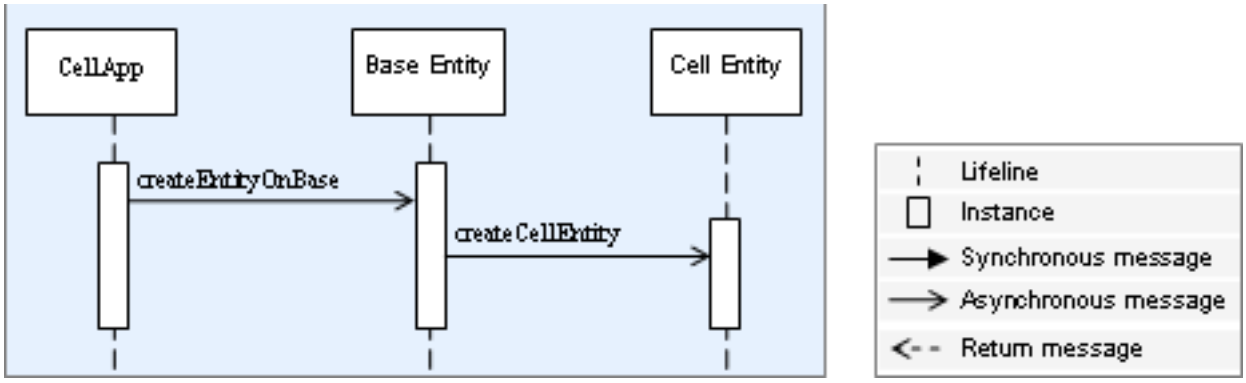
```
def createEntityOnBaseApp( entityTypeName, properties ):
```

Method `BigWorld.createEntityOnBaseApp`'s signature

This function takes the following parameters:

- ***`entityTypeName`*** - Name of the entity type to create.
- ***`properties`*** - A dictionary of properties on the base as listed in the entity's definition file.

This function dispatches a message to a BaseApp to create a base entity, which can later call method `createCellEntity` to create the cell entity.



Creation of cell entity with its base counterpart

8.5. Loading Entities From Chunk Files

WorldEditor can be used to insert entity placeholders into chunks. These placeholders can be read by Python script on the server to load these entities into the game world using the `BigWorld.fetchEntitiesFromChunks` method on BaseApps.

The following example code is taken from `fantasydemo/res/scripts/base/TeleportPoint.py`:

```
class TeleportPoint( BigWorld.Base ):
  ...
  BigWorld.fetchEntitiesFromChunks( self.geometry, EntityLoader( self ) )


class EntityLoader:
```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```
def __init__( self, dstEntity ):
  self.dstEntity = dstEntity


def onSection( self, entityDataSection, matrix ):
  e = BigWorld.createEntity(
    entityDataSection.readString( "type" ),
    entityDataSection[ "properties" ],
    createOnCell = self.dstEntity.cell,
    position = matrix.applyToOrigin(),
    direction = (matrix.roll, matrix.pitch, matrix.yaw))
```

fantasydemo/res/scripts/base/TeleportPoint.py

The `BigWorld.fetchEntitiesFromChunks` method causes all chunks in the space to be loaded in a loading thread. Each `<entity>` data section in the loaded chunks causes the method `onSection` to be called on the handler object. This method can then use the data section to create an appropriate entity.

For more details on loading data section information in a thread-safe way, see both the document How To Avoid Files Being Loaded in the Main Thread and the BaseApp Python API documentation's entries **Main Page → Base → BigWorld → Function → `BigWorld.fetchDataSection`**, **`BigWorld.fetchEntitiesFromChunks`**, and **`BigWorld.fetchFromChunks`**.

Chapter 9. The Database Layer

The database layer is BigWorld's persistent storehouse of entities. It allows writing specific entities into online storage (usually into a database table or disk file), and retrieving them back into the world again later.

The database layer is not intended to be accessed frequently by each entity, but instead only at entity creation and destruction times (and perhaps at critical trade points). You should not attempt to access the database in response to every action a character performs - let the disaster recovery mechanisms handle game integrity.

This chapter provides details on how to store and retrieve entities from the database.

9.1. Persistent Properties

The first step to make an entity persistent is to edit its definition file (named `<res>/scripts/entity_defs/<entity>.def`) and specify the properties to be made persistent.

The persistent set of properties is often a small subset of the entity properties. For example, a role playing game typically has a set of core attributes (strength, dexterity, etc...), and a set of derived attributes that need to be modified transiently (maybe the character always gets full vitality when logging on, and so vitality points need not be persisted).

To mark an entity property as persistent, it needs the tag `<Persistent>` added to it, as illustrated below:

```
<root>
  ...
  <Properties>
    ...
    <somePersistentProperty>
      <Type>       TYPENAME </Type>
      <Flags>      FLAGS    </Flags>
      <Persistent> true     </Persistent>
    </somePersistentProperty>
    ...
  </Properties>
  ...
</root>
```

`<res>/scripts/entity_defs/<entity>.def` - Marking a property as persistent

If the type is FIXED_DICT, then the `<Persistent>` tag can be specified for each property of the FIXED_DICT data type.

For example:

```
<root>
  ...
  <Properties>
    ...
    <someFixedDictProperty>
      <Type>    FIXED_DICT
        <Properties>
          <a> <Type> TYPENAME </Type> </a>
          <b>
            <Type> TYPENAME </Type>
            <Persistent> false </Persistent>
          </b>
        </Properties>
      </Type>
```

```
      <Flags>    FLAGS      </Flags>
      <Persistent>  true    </Persistent>
    </somePersistentProperty>
    ...
  </Properties>
  ...
</root>
```

In the above example, `someFixedDictProperty.a` is persistent, but `someFixedDictProperty.b` is not. If the `<Persistent>` tag at the `<someFixedDictProperty>` level is `false`, then neither `a` nor `b` will be persistent. By default, the `<Persistent>` tag at the FIXED_DICT field level is `true`, so it is not necessary to specify it, except for selectively turning off the persistence of some fields.

During startup, the database process (DBMgr) automatically allocates the tables, fields, or other storage required for persistent properties. Sometimes this behaviour is not desirable (for example in a production system), and it can be controlled with the `<dbMgr/syncTablesToDefs>` configuration option. For details on this option, see the document Server Operations Guide's section Software Configuration with `bw.xml` → DBMgr configuration options.

Other parameters can be set for persistent properties for the MySQL database engine. For more details, see “Mapping BigWorld Properties Into SQL” on page 70 .

9.1.1. Non-Persistent Properties

Properties that are reset each time the entity is created should not be made persistent. For example, entity's A.I. and GUI states are usually non-persistent. Reducing the number of persistent properties will reduce the load on the database. If a property is not persistent, its value will be set to its default value when the entity is loaded from the database (see “Reading and Writing Entities” on page 68).

A MAILBOX property is always non-persistent.

9.1.2. Built-In Properties

The following built-in properties are persistent:

- **Base** : `databaseID` .
- **Cell** : `position` , `direction` and `spaceID` .

All other built-in properties are non-persistent.

Note

The entity's built-in `id` property is not persistent. It will change each time the entity is re-created. This includes the case where the entity is re-created automatically by the disaster recovery mechanism (see *Disaster Recovery* on page 106). Therefore, when storing entity IDs of other entities, they should be stored in non-persistent properties so that they will be automatically reset to the properties' default value when the entity is re-created by the disaster recovery mechanism. This avoids the possibility of storing invalid entity IDs.
The entity's `id` property is unchanged when the entity is restored by our fault tolerance mechanism (see *Fault Tolerance* on page 103).
Use the entity's database ID for a long term reference to the entity.

9.1.3. The Identifier Tag

The `<Identifier>` tag is an optional tag for persistent STRING or BLOB entity properties. It specifies a property to be the identifier for that entity type. Entities can be retrieved from the database by using

their identifier instead of their database ID. For this reason, all entities of the same type must have unique identifiers. At most one property per entity can be tagged as an identifier.

For example, assuming the entity definition file below:

```
<root>
  ...
  <Properties>
    ...
    <playerNickname>
      <Type>       STRING </Type>
      <Flags>      Flags  </Flags>
      <Persistent> true   </Persistent>
      <Identifier> true   </Identifier>
    </playerNickname>

    <someProperty1>
      <Type>       UINT32 </Type>
    </someProperty1>

    <someProperty2>
      <Type>       STRING </Type>
      <Persistent> true   </Persistent>
    <someProperty2>
    ...
```

Example <*res*>/scripts/entity_defs/<*entity*>.def - Setting the Identifier property

Then assuming that there are three instances of the above entity type, they could be represented like in the table below:

playerNickname	someProperty2
playerNickname1	"cfeh"
playerNickname2	"fwep"
playerNickname3	"fwep"

Note that <someProperty1> is not represented in the database because it is not specified as being persistent.

Entity types with an <Identifier> property can be searched by name, using methods such as BigWorld.lookUpBaseByName and BigWorld.createBaseFromDB. For details, see the BaseApp Python API documentation.

9.2. Reading and Writing Entities

The database provides the means of saving entities and bringing them back into the world at a later time. It also guarantees that each saved entity can have only one instance within the world. This assures that any writes to the database for the entity will be correctly carried out.

In order to use this functionality, you must first create a persistent entity. Such an entity must exist on a BaseApp, and could be of type BigWorld.Base or BigWorld.Proxy. You can create it with any of the normal techniques. For more details, see “Entity Instantiation on the BaseApp” on page 59 .

The key for persisting an entity is its property databaseID, combined with its entity type. The property databaseID is a 64-bit integer that is unique among entities of the same type, and usually corresponds to

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an auto-increment field in a database table. When an entity is created with any of the usual techniques, its `databaseID` is set to 0, indicating that it has never been written to the database.

To add a newly created entity to the database, its method `writeToDB` has to be invoked (from either cell or base).

If invoked on the base entity, `writeToDB` receives an optional argument specifying the callback method. Upon completion, `writeToDB` will invoke the callback, passing a Boolean argument indicating if writing to the database succeeded or failed, and the base entity that invoked the method. A notification method is used, as the database write is an asynchronous operation.

The code fragments below illustrate the use of method `writeToDB` from the base.

1. In `someEntity`'s base script (`<res>/scripts/base/someEntity.py`), define callback method for `writeToDB`:

```
import BigWorld

class someEntity( BigWorld.Base )
  ...
  def onWriteToDBComplete( successful, entity ):
    if successful:
      print "write %i OK. databaseID = %i" % (entity.id, databaseID)
    else:
      print "write %i was not successful" % entity.id
  ...
```

2. Invoke methods to create base and add it to database:

```
ent = BigWorld.createBase( "someEntity" )
ent.writeToDB( onWriteToDBComplete )
```

3. The result displayed in BaseApp:

```
write 92 OK. databaseID = 376182
```

Next time this entity is destroyed (by invoking method `ent.destroy`), it will be 'logged off' - the database layer keeps track of whether the entity is in the world.

A destroyed entity can later be brought back to the world using the method `BigWorld.createBaseFromDBID` and the properties stored in the database, as illustrated below:

```
BigWorld.createBaseFromDBID( "someEntity", 376182, optionalCallbackMethod )
```

Since loading a destroyed entity from the database is also an asynchronous operation, if you wish to be notified of the completion of this process, you need to pass a callback function as the third argument of method `BigWorld.createBaseFromDBID`. The callback function receives the entity identifier as the only argument, which is the `databaseID` if entity was successfully loaded, or `None`, otherwise.

The code fragments below illustrate the request to reload entities from the database:

1. In `someEntity`'s base script (`<res>/scripts/base/someEntity.py`), define callback method for `createBaseFromDBID`:

```
import BigWorld

def onComplete( entity ):
  if entity is not None:
    print "entity successfully created"
  else:
    print "entity was not created"
```

2. Call `createBaseFromDBID` with a valid `databaseID`:

```
BigWorld.createBaseFromDBID( "someEntity", 376182, onComplete )
```

3. The result displayed in BaseApp:

```
entity successfully created
```

4. Call `createBaseFromDBID` with an invalid `databaseID`:

```
BigWorld.createBaseFromDBID( "someEntity", 10000000000, onComplete )
```

5. The result displayed in BaseApp:

```
entity was not created
```

9.3. Mapping BigWorld Properties Into SQL

When designing persistent properties, it is useful to understand how the mapping from BigWorld types to SQL types is performed by the database layer. This information can be used for performance tuning, or in manually modifying the database.

9.3.1. Entity Tables

Each entity type will have a main entity table, and zero or more sub-tables in the database.

An entity type's main table is named `tbl_<entity_type_name>`. Data for the majority of BigWorld types will be stored in the columns of the main table. Types like ARRAY and TUPLE, however, require the use of additional tables, referred to as sub-tables in this document.

Except for ARRAY and TUPLE properties, data for each entity is stored as a single row in the entity type's main table.

9.3.2. The `databaseID` property

The `databaseID` property of an entity is stored in the id column in the main table - this is why entities without persistent properties still have a main entity table.

9.3.3. Simple Data Types

A property with a simple data type is mapped to a single SQL column (named `sm_<property_name>`) with a type that accommodates.

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The table below describes each BigWorld simple data type, and which MySQL type it is mapped to:

BigWorld data type	Mapped to MySQL type (column sm_<property_type>)
INT8	TINYINT
UINT8	TINYINT UNSIGNED
INT16	SMALLINT
UINT16	SMALLINT UNSIGNED
INT32	INT
UINT32	INT UNSIGNED
INT64	BIGINT
UINT64	BIGINT UNSIGNED
FLOAT32	FLOAT
FLOAT64	DOUBLE

9.3.4. VECTOR Data Types

Properties with vector types are mapped to the appropriate number of columns of MySQL type FLOAT - named `vm_<index>_<property_name>`, where `<index>` is a number from 0 to the size of the vector minus 1.

The list below describes each BigWorld VECTOR data type, and which MySQL type it is mapped to:

BigWorld data type	# of columns	Mapped to MySQL type (column vm_<index>_<property_name>)
VECTOR2	2	FLOAT
VECTOR3	3	FLOAT
VECTOR4	4	FLOAT

9.3.5. STRING, BLOB, and PYTHON Data Types

Properties of types STRING, BLOB, and PYTHON will be mapped to column `sm_<property_name>`, with the type being dependent on the `<DatabaseLength>` attribute of the property specified in the entity definition file (for details, see "The Entity Definition File" on page 12 , and *Properties* on page 17), as it determines the width of the column when the type is mapped to SQL.

The list below summarises the mapping of STRING, BLOB, and PYTHON data types:

- **PYTHON**
  - **DatabaseLength** < 256 - TINYBLOB
  - **DatabaseLength** >= 256 and < 65536 - BLOB
  - **DatabaseLength** >= 65536 and < 16777215 - MEDIUMBLOB

- **STRING**
  - **DatabaseLength < 256** - VARCHAR
  - **DatabaseLength >= 256 and < 65536** - TEXT
  - **DatabaseLength >= 65536 and < 16777215** - MEDIUMTEXT

The definition of <DatabaseLength> is illustrated below:

```
<root>
  ...
  <Properties>
    ...
    <someProperty>
      <Type>           STRING  </Type>
      <DatabaseLength> 16      </DatabaseLength>
    </someProperty>
    ...
```

<res>/scripts/entity_defs/<entity>.def - Defining property's mapped SQL type

9.3.6. PATROL_PATH and UDO_REF Data Types

The PATROL_PATH type has been deprecated in favor of the use of User Data Objects and should be avoided as they will be removed in a future release. The <PatrolNode> User Data Object replaces the station nodes of the old system.

Properties with UDO_REF type are mapped to a column of type BINARY, named sm_<*property_name*>. The column width is 16 bytes, which corresponds to the 128-bit GUID that identifies a Patrol Path or User Data Object type.

The 128-bit GUID is stored in the column as four groups of 32-bit unsigned integers. Each integer is in little endian order. For example, if the GUID is 00112233.44556677.8899AABB.CCDDEEFF, then the byte values in the column will be 3322110077665544BBAA9988FFEEDDCC.

9.3.7. ARRAYs and TUPLEs

Each ARRAY or TUPLE property is mapped to an SQL table, referred to as sub-tables of the entity's main table, and named <*parent_table_name*>_<*property_name*>.

<*parent_table_name*> is the name of the entity type's main table, unless the ARRAY or TUPLE is nested in another ARRAY or TUPLE property, in which case <*parent_table_name*> is the name of the parent ARRAY's or TUPLE's table.

Note

Although BigWorld does not impose a limit on nesting ARRAY or TUPLE types, MySQL has a limit of 64 characters on table names.
As sub-table names are always prefixed with their parent table name, this effectively limits the nesting depth.

ARRAY or TUPLE sub-tables have a parentID column that stores the id of the row in the parent table associated with the data. The sub-table will also have an id column to maintain the order of the elements, as well as to provide a row identifier in case there are sub-tables of this sub-table.

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The other columns of the sub-table will be determined by the ARRAY's or TUPLE's element type (*e.g.*, an `ARRAY <of> INT8 </of>` will result in one additional column of type TINYINT). Most BigWorld types only require one additional column, which will be called `sm_value`. For details on how an ARRAY or TUPLE of FIXED_DICT is mapped into the database, see "FIXED_DICTs" on page 73 .

9.3.7.1. The <DatabaseLength> Attribute

The `<DatabaseLength>` attribute of an ARRAY or TUPLE property is applied to the element type of the array if the element type is STRING, BLOB or PYTHON.

Other types either disregard the `<DatabaseLength>` modifier or, as in the case of FIXED_DICT, have their own method of specifying the `<DatabaseLength>`.

9.3.8. FIXED_DICTs

If an entity type contains a FIXED_DICT property, then that property's fields are mapped to the database as though they where properties of the entity.

FIXED_DICT columns have more elaborate names than non-FIXED_DICT columns:

- `sm_<property_name>_<field_name>`

If the FIXED_DICT property contains an ARRAY or TUPLE field then the name of the sub-table is correspondingly more elaborate:

- `<parent_table_name>_<property_name>_<field_name>`.

If a FIXED_DICT type is used as an element of an ARRAY or TUPLE, then the fields are mapped into the columns of the ARRAY's or TUPLE's sub-table. The columns will be named `sm_<field name>`.

If the FIXED_DICT property has the `<AllowNone>` attribute set to `true`, then an additional column called `fm_<property_name>` will be added to the table. This column will have the value `0` when the property's value is `None`, or `1` otherwise.

The `<DatabaseLength>` attribute should be specified at the field level of a FIXED_DICT property - the one specified at the property level is ignored.

9.3.9. USER_TYPEs

If you have a USER_TYPE data type, then you can specify how it should be mapped to SQL. For more details on custom data types, see "Implementing Custom Property Data Types" on page 30 .

In order to provide this mapping, a method called `bindSectionToDB` needs to be implemented in the USER_TYPE implementation. This method receives an object as its argument to be used to declare the data binding. For example, for a USER_TYPE implemented by an instance of the type TestUserType:

```
...
  class TestUserType:
    ...
    def addToStream( self, obj ):
      ...

    def bindSectionToDB( self, binder ):
      ...

instance = TestUserType()
```

Defining USER_TYPE database mapping method.

The object received by `bindSectionToDB` to perform the type mapping (*`binder`* in the preceding example) provides the following methods:

- **`bind(`*`property`*`,`*`type`*`,`*`databaseLength`*`)`**

  Binds a property (based on name) from the data section to a field (or fields) in the current SQL table, and creates a column called `sm_<`*`property_name`*`>`.

  The parameter type is a string that corresponds to the `<Type>` field of the XML definition of the property. For example:

Data type	XML	type
Simple	`<Type> INT </Type>`	INT
ARRAY	`<Type> ARRAY <of> INT</of> </ Type>`	`ARRAY <of> INT</of>`
Custom	`<Type> USER_TYPE <implementedBy> module.instance </implementedBy> </Type>`	`USER_TYPE <implementedBy> module.instance </implementedBy>`

  The parameter *`databaseLength`* is optional (defaulting to 255), and determines the size and data type of STRING mapped. For more details, see “STRING, BLOB, and PYTHON Data Types” on page 71 .

- **`beginTable(`*`property`*`)`**

  Starts the specification of a new SQL table (called `<`*`current_table_name`*`>_<`*`property_name`*`>`) for binding Python compound objects *e.g.* lists, tuples, dictionaries. Any calls to the method `bind` following a `beginTable` call will bind to fields in the new table until `endTable` is called.

  Typically, `beginTable` is only used for binding Python compound objects that contains a variable number of compound objects *e.g.* list of tuples. For simple lists and tuples, it is sufficient to call bind with '`ARRAY <of><simple_type></of>`' as the type. For compound objects that contain a fixed number of items, it is more efficient to bind each item as a separate field in parent table instead of creating a new table.

  All tables created by `beginTable` will have an additional field called *`parentID`* used in associating rows in the new table with the parent table.

- **`endTable()`**

  Finishes the specification of new SQL table started by method `beginTable`.

  Upon completion, specification of the parent table is resumed.

The implementation of the method `bindSectionToDB` must match the implementation of the method `addToStream`. The order and the parameter type of calls to `bind` must match the order in which the properties are serialised.

The table below shows the `addToStream` implementation followed by the corresponding `bindSectionToDB` implementation:

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addToStream implementation	Corresponding bindSectionToDB implementation
`stream += struct.pack ( "b", obj.intValue )`	`binder.bind( "intValue", "INT8" )`
`stream += struct.pack ( "B", obj.intValue )`	`binder.bind( "intValue", "UINT8" )`
`stream += struct.pack ( "h", obj.intValue )`	`binder.bind( "intValue", "INT16" )`
`stream += struct.pack ( "H", obj.intValue )`	`binder.bind( "intValue", "UINT16" )`
`stream += struct.pack ( "i", obj.intValue )`	`binder.bind( "intValue", "INT32" )`
`stream += struct.pack ( "I", obj.intValue )`	`binder.bind( "intValue", "UINT32" )`
`stream += struct.pack ( "q", obj.intValue )`	`binder.bind( "intValue", "INT64" )`
`stream += struct.pack ( "Q", obj.intValue )`	`binder.bind( "intValue", "UINT64" )`
`stream += struct.pack ( "f", obj.floatValue )`	`binder.bind( "floatValue", "FLOAT32")`
`stream += struct.pack ( "b", len(obj.stringValue) ) + stringValue`	`binder.bind( "stringValue", "STRING", 50)`

`stream += struct.pack ( "i", len(obj.listValue) ) for item in obj.listValue stream += struct.pack ( "f", item )`	`binder.beginTable( "listValue" ) binder.bind( "value", "FLOAT32" )`
	`binder.endTable()`
	or
	`binder.bind( "listValue", "ARRAY <of> FLOAT32 </of>" )`

9.3.9.1. Examples

- **Mapping a simple user-defined data type**

  The example below illustrates a simple user data type that represents a UTF-8 string.

  It maps the Python type unicode to a BigWorld data type. The method `bindSectionToDB` binds the property to a 50-byte SQL string column. Since this type requires only one column, there is no need to give it a name, thus the property argument can be an empty string.

```
class UTF8String():
  "
  UTF8(unicode) string
  "
  def addToStream( self, obj ):
    # obj is a Python Unicode object.
    string = obj.encode( "utf-8" )
    return struct.pack( "b", len(string) ) + string

  def addToSection( self, object, section ):
    # Since UTF-8 is compatible to C strings(no NULL characters)
    # it is safe to store a Unicode string as C string.
    # The asString setter/getter method stores the value in the
    # root of DataSection 'section'.
    section.asString = obj.encode( "utf-8" )

  def createFromStream( self, stream ):
    # Return a Python Unicode object.
    (length,) = struct.unpack( "b", stream[0] )
    string = stream[ 1 : length+1 ]
    return string.decode( "utf-8" )

  def createFromSection( self, section ):
    # The asString method returns the value of section root
```

```
    # as a simple C string.
    # Return a Python Unicode object.
    return section.asString.decode( "utf-8" )

  def bindSectionToDB( self, binder ):
    # The empty string represents the root of DataSection.
    # The value in the DataSection root will be stored in
    # SQL database as a column of STRING type
    binder.bind( "", "STRING", 50 )

  def defaultValue( self ):
    # Return an empty Python Unicode object.
    return u""

instance = UTF8String()
```

<res>/scripts/common/UTF8String.py

- **Mapping a complex user-defined type**

The example below implements the class `Test`, and the class `TestDataType`, which accesses the values on `Test`.

`Test` contains three member variables:

- An integer.
- A string.
- A dictionary.

`TestDataType`'s method `addToSection` will represent the attributes of `Test` objects like the following `<DataSection>`:

```
<testData>

  <intValue>    100        </intValue>

  <stringValue> opposites  </stringValue>

  <dictValue>
    <value>
      <key>    good     </key>
      <value>  bad      </value>
    </value>
     <value>
      <key>    old      </key>
      <value>  new      </value>
    </value>
    <value>
      <key>    big      </key>
      <value>  small    </value>
    </value>
  </dictValue>

</testData>
```

`Test` object's `DataSection`

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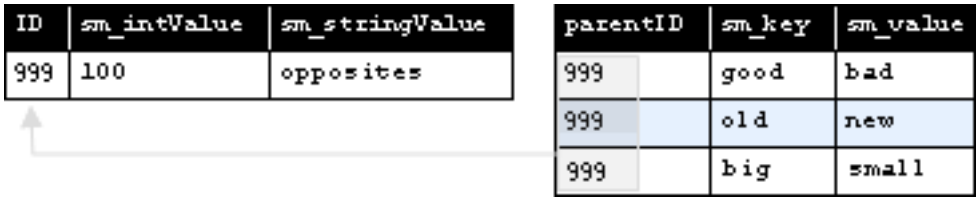
`TestDataType`'s method `createFromSection` will create `Test` objects from `DataSection`s like the one above.

`TestDataType`'s method `bindSectionToDB` will bind the `Test` object's integer and string variables to two columns, and add a child table for the dictionary member, as illustrated below:



ID	sm_intValue	sm_stringValue
999	100	opposites

parentID	sm_key	sm_value
999	good	bad
999	old	new
999	big	small

Representation of Test entity data in the MySQL database

The classes `Test` and `TestDataType` are defined as below:

```
import struct

class Test:
  def __init__( self, intValue, stringValue, dictValue ):
    self.intValue = intValue
    self.stringValue = stringValue
    self.dictValue = dictValue

  def writePascalString( string ):
    return struct.pack( "b", len(string) ) + string

  def readPascalString( stream ):
    (length,) = struct.unpack( "b", stream[0] )
    string = stream[1:length+1]
    stream = stream[length+1:]
    return (string, stream)

class TestDataType:
  def addToStream( self, obj ):
    if not obj: obj = self.defaultValue()
    stream = struct.pack( "i", obj.intValue )
    stream += writePascalString( obj.stringValue )
    for key in obj.dictValue.keys():
      stream += writePascalString( key )
      stream += writePascalString( obj.dictValue[key] )
    return stream

  def createFromStream( self, stream ):
    (intValue,) = struct.unpack( "i", stream[:4] )
    stream = stream[4:]
    stringValue, stream = readPascalString( stream )
    dictValue = {}
    while len(stream):
      key, stream = readPascalString( stream )
      value, stream = readPascalString( stream )
      dictValue[key] = value
    return Test( intValue, stringValue, dictValue )

  def addToSection( self, obj, section ):
    if not obj: obj = self.defaultValue()
    section.writeInt( "intValue", obj.intValue )
    section.writeString( "stringValue", obj.stringValue )
    s = section.createSection( "dictValue" )
```

```
    for key in obj.dictValue.keys():
      v = s.createSection( "value" )
      print key, obj.dictValue[key]
      v.writeString( "key", key )
      v.writeString( "value", obj.dictValue[key] )


  def createFromSection( self, section ): 1
    intValue = section.readInt( "intValue" )
    if intValue is None:
      return self.defaultValue()
    stringValue = section.readString( "stringValue" )
    dictValue = {}
    for value in section["dictValue"].values():
      dictValue[value["key"].asString] = value["value"].asString
    return Test( intValue, stringValue, dictValue )

  def fromStreamToSection( self, stream, section ):
    o = self.createFromStream( stream )
    self.addToSection( o, section )

  def fromSectionToStream( self, section ):
    o = self.createFromSection( section )
    return self.addToStream( o )

  def bindSectionToDB( self, binder ):
    binder.bind( "intValue", "INT32" )
    binder.bind( "stringValue", "STRING", 50 )
    binder.beginTable( "dictValue" )
    binder.bind( "key", "STRING", 50 )
    binder.bind( "value", "STRING", 50 )
    binder.endTable()

  def defaultValue( self ):
    return Test(100, "opposites", {"happy":"sad", "big":"small",
 "good":"bad"})

instance = TestDataType()
```

<res>/scripts/common/TestDataType.py

For details on methods supported for `DataSection` objects, see the BaseApp Python API documentation, CellApp Python API documentation, and Client Python API documentation's entry **Class list → DataSection**.

1

Note

This script function does not process the input command and its corresponding output - the input command is handled by the database management system. It is the user's responsibility to ensure that the command is compatible with the underlying database. The command's output should be processed by the callback function provided by the user.

9.4. Execute Arbitrary Commands on Database

BigWorld provides a facility for developers to execute arbitrary commands on the underlying database. By using the method `BigWorld.executeRawDatabaseCommand` you can execute custom statements or commands, and access data that do not conform to the standard BigWorld database schema.

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Each database interface can interpret the data (command) and convert it to the expected format. For example, the MySQL interface expects an SQL statement, and the XML interface expects a Python statement.

9.4.1. Execute Commands on SQL Database

When executing a command on a SQL database, the method `BigWorld.executeRawDatabaseCommand` has the following signature:

```
BigWorld.executeRawDatabaseCommand( sql_statement, sqlResultCallback )
```

It has the following parameters:

- ***sql_statement***

  The SQL statement to execute. For example: '`select * from tbl_Avatar`'.

- ***sqlResultCallback***

  The Python callback to be invoked with the result from SQL.

The callback will be invoked with the following parameters:

- ***resultSet*** **(List of list of strings)**

  For SQL statements that return a result set (such as `SELECT`), this is a list of rows, with each row being a list of strings.

  For SQL statements that do not return a result set (such as `DELETE`), this is `None`.

- ***affectedRows*** **(Integer)**

  For SQL statements that return a result set (such as `SELECT`), this is `None`.

  For SQL statements that do not return a result set (such as `DELETE`),this is the number of affected rows

- ***error*** **(String)**

  If there was an error in executing the SQL statement, this is the error message. Otherwise, this is `None`.

9.4.2. Execute Commands on XML Database

When executing a command on a XML database, the method `BigWorld.executeRawDatabaseCommand` has the following signature:

```
BigWorld.executeRawDatabaseCommand( python_statement, pythonResultCallback )
```

It has the following parameters:

- ***python_statement***

  The Python expression to execute

- ***pythonResultCallback***

  The Python callback to be invoked with the result from the Python expression.

The XML database is stored in a global data section named `BigWorld.dbRoot`. The structure of the data section is defined by the entity definition files (`<res>/scripts/entity_defs/<entity>.def`).

The callback is called with three parameters:

- **`resultSet` (List of list of strings)**

  Output of the Python expression, as a string.

  The string is embedded inside two levels of lists, so `resultSet[0][0]` retrieves the string.

- **`affectedRows` (Integer)**

  This parameter will always be `None`.

- **`error` (String)**

  If there was an error in executing the Python expression, this is the error message. Otherwise, this is `None`.

The code fragments below execute a command on the XML database:

1. Request the health level of an avatar called '`Fred`':

```
BigWorld.executeRawDatabaseCommand(
    "[a[1]['health'].asInt for a in BigWorld.dbRoot.items() if
 a[0]=='Avatar' and a[1]['playerName'].asString == 'Fred']", healthCallback
 )
```

2. Implement the Python callback:

```
def healthCallback( result, dummy, error ):
    if (error):
         print "Error:", error
         return
    print "Health:", result[0][0]
```

3. If the avatar's health level is 87, then the output will be:

```
Health: [87]
```

9.5. Secondary Databases

Secondary databases are an optional feature that can be used to help reduce load on the primary database by distributing database writes onto machines with BaseApp processes. After an entity has been loaded from the primary database onto a BaseApp they are considered *active* and store any property modifications into a secondary database stored on the same machine as their associated BaseApp. Secondary databases will write back their contents to the primary database after an active entity is destroyed, becoming inactive.

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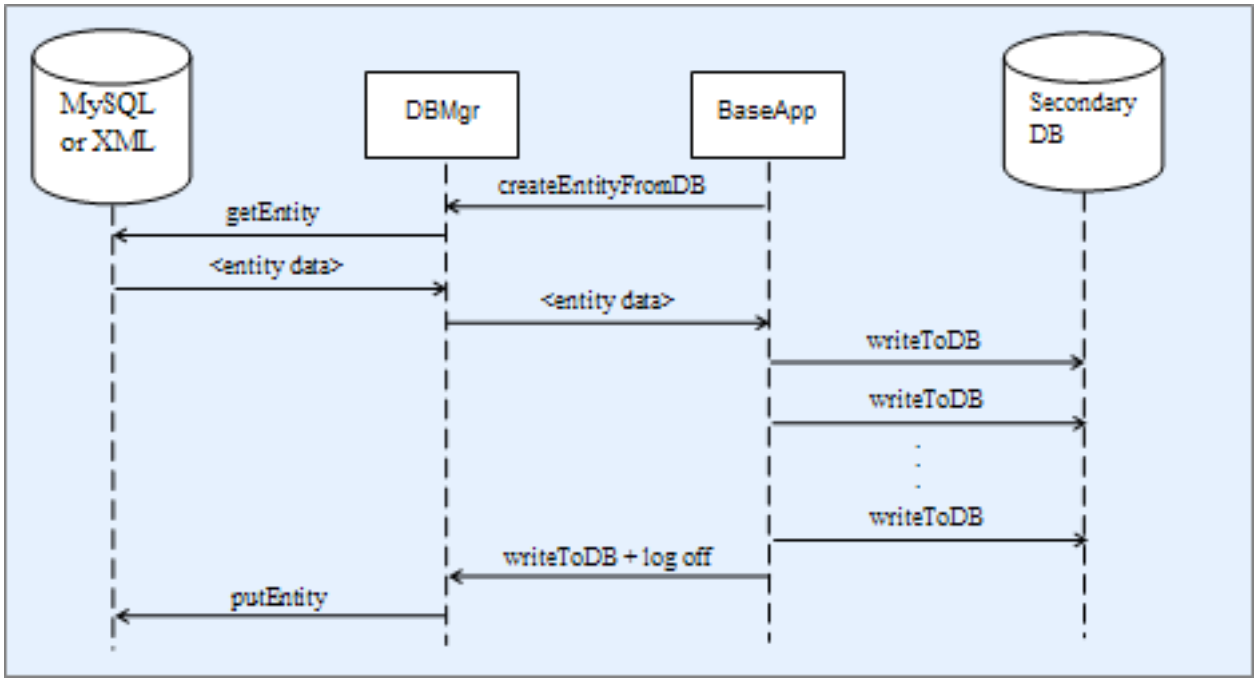

Flow of persistent entity data when secondary databases are enabled

Each BaseApp has its own secondary database, including machines which may host more than one BaseApp. A secondary database is an SQLite database file on the BaseApp machine's local disk. Secondary databases can be enabled or disabled using the `<baseApp/secondaryDB/enable>` configuration option. For details on this option, see the document Server Operations Guide's section *Server Configuration with* `bw.xml` → "Secondary Database Configuration Options" .

Entities are currently stored in raw binary form inside secondary databases and should only be manipulated using BigWorld tools like the data consolidation tool **consolidate_dbs**.

9.5.1. Data Consolidation

In case of a complete system failure, active entities may not have the opportunity to flush their data to the primary database. The data consolidation tool is run to transfer the active entity data from secondary databases to the primary database.

The data consolidation process is automatically run during system shutdown to transfer the persistent data of entities that were active when the system was shutdown.

The data consolidation tool is automatically run during start-up if the system was not shutdown successfully.

Unlike the BigWorld server, which uses UDP for interprocess communications, the data consolidation tool uses TCP connections to transfer the secondary databases from the BaseApp machines to the DBMgr machine. If there is a firewall on the DBMgr machine, it needs to be configured to allow TCP connections from BaseApp machines.

For more details on the data consolidation tool, see the document Server Operations Guide's section "Data Consolidation Tool".

9.5.2. Database Snapshot

Due to the existence of secondary databases, the data in the primary database may be quite stale. A backup made of the primary database may be considered too stale for functional use. As a solution to this issue, a secondary database snapshot tool is provided to make more up-to-date backups by backing up data from

secondary databases as well. For details, see the document Server Operations Guide's section “Database Snapshot Tool”.

Note

Despite the name of the tool, it does not generate a true snapshot of the system. The tool does not ensure that all active entities have flushed their data to the secondary databases before taking a copy of the secondary database. It makes a best effort at copying the primary and all the secondary databases at close to the same time.

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Chapter 10. Proxies and Players

10.1. Proxies

The class `BigWorld.Proxy` on the BaseApp extends `BigWorld.Base` to support player-controlled entities. By deriving an entity from `BigWorld.Proxy`, you can implement player characters, their accounts, and any other relevant player-controlled objects on the server.

An entity derived from `BigWorld.Proxy` is created from the database whenever a client logs in to the server. For details on how BigWorld determines which Proxy to load, see *User Authentication and Proxy Selection* on page 114. Proxies created in this way (see below for other ways of creating proxies) which have a property called `password`, will have the value of that property set to the login password.

An instance of `BigWorld.Proxy` needs neither a cell entity, nor a client one. A proxy entity can be created using the method `BigWorld.createBase`, just like any other entity. For more detail on this method, see "Entity Instantiation on the BaseApp" on page 59 .

Like other base entities, saving and loading proxy entities from the database is possible. Initially, these reloaded proxy entities will be created without an attached client. An existing proxy can later hand its client over to the reloaded one, in which case the reloaded proxy will be the one handling the client connection.

This allows you to have, for example, an `Account` entity that people can log in to, and a `Character` entity that people can select from a menu in order to use in the game.

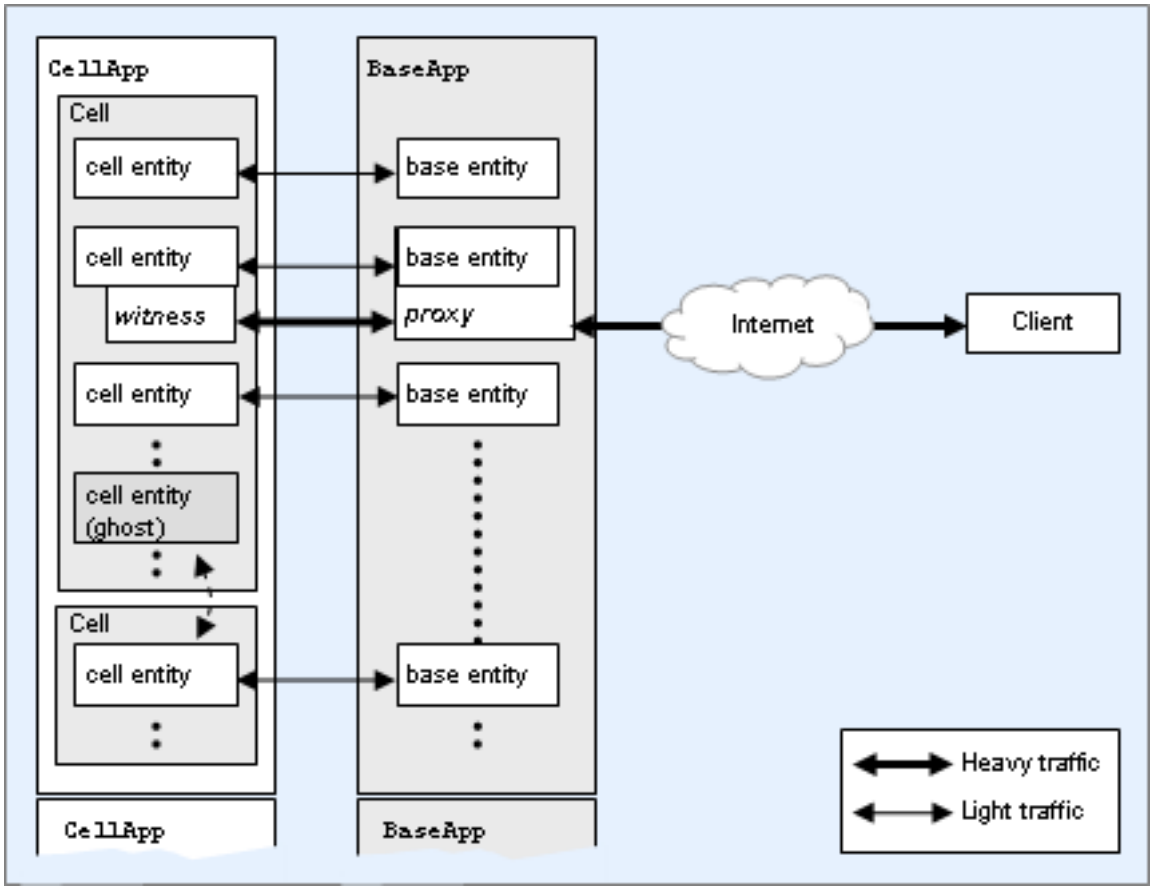
To pass the control of a client from one proxy to another, use the method `giveClientTo`, as in the example below:

```
clientControlledProxy.giveClientTo( nonClientControlledProxy )
```

Note

In order to pass the control between proxies, both proxy entities must be on the same BaseApp.

Whenever a client moves between proxies, or the cell entity of the proxy that a client is attached to is destroyed, the client receives a call on `onEntitiesReset` to clear out its current knowledge of the world. This effectively interrupts all game communications, and forces the client to refresh. If only the cell entity has been destroyed, then the client's knowledge of its proxy is retained.



BaseApp managing bases and proxies

10.2. Witnesses

Whenever a proxy with an attached client has a corresponding cell entity, an extra object called witness is attached to the cell entity.

This object manages the entity's AoI, and sends updates to the proxy, which forwards them on to the client.

The updates consist of the bulk of game-related messages, such as:

- Entity position updates.
- Entity property updates.
- Method calls.
- Space data changes.
- Notifications of entities entering and leaving the AoI.

10.3. Entity Control

By default, every cell entity is considered to be controlled by the server. When an entity incorporates a witness object, it is considered to be controlled by the client attached to the corresponding proxy.

However, the control of an entity may be explicitly assigned and queried, using the entity attribute `.controlledBy`. This attribute may be set to `None`, to indicate server control, or to a `BaseEntityMailBox` to indicate control by the client attached to that proxy. Within this context, control implies ownership of and

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responsibility for the entity's position and direction. Clients (and proxies) are informed of changes to the set of entities that they are allowed to control. Proxies may read this set through their attribute wards.

10.4. Physics Correction

When an entity is controlled by a client, setting the attribute `Entity.topSpeed` to a value greater than zero enables the physics checking. By default the `topSpeed` enables physics checking on all 3 axis, however this may not always be appropriate. For example, if the gravity of your game environment enables a Y-axis acceleration that results in a top speed exceeding the maximum allowable X/Z-axis top speed. In order to accommodate this there is a secondary attribute named `Entity.topSpeedY` which takes precedence when set to a value greater than zero. `topSpeedY` will only be used when both `topSpeed` and `topSpeedY` are greater than zero.

Entity movement is validated in the following ways:

- **Speed**

  The first check is regarding the speed, to ensure that it does not exceed `topSpeed` and `topSpeedY`. There is a small amount of variance allowed in speed to account for up to 150ms of network jitter. Care is taken so that this *latency debt* is not exploited by allowing the player to travel faster than the top speed for a brief period of time.

- **Geometry of the scene**

  The second check is made against the geometry of the scene, to ensure that the entity only leaves its current chunk through a well-defined portal.

  In spite of being very fast, this check does have consequences for level design. Barriers that control character mobility must be represented at the level of chunks. For example, a chunk with a wall across it, and a door giving access to the other side, is not protected by this physics checking system. In order to implement this in a manner to enable physics validation, two chunks should be used one on each side of the wall, with the door as a portal between them.

- **Custom physics validator**

  If a custom physics validator has been developed, it will then be called between the top speed and the geometry checks. The custom physics validator is called with the following parameters:

  - Pointer to the entity.
  - Pointer to the vehicle (`NULL` if the entity is not on a vehicle).
  - The position to which the entity wants to move.
  - The time elapsed since the last physics check.

  The custom physics validator should return `true` if the entity is allowed to move to the new position, or `false` if it is not allowed.

  To install a custom physics validator, a CellApp extension module must be written. During the initialisation of the extension module, the global function pointer `g_customPhysicsValidator` (declared in `bigworld/src/server/cellapp/entity.hpp`) should be set to point to the custom physics validator function. For more details, see *Extending BigWorld Server* on page 133 .

Other scenarios in which physics checking is applied include:

- Control of multiple entities by the same client (such as wards).
- Movement between vehicles (the ghost methods `onPassengerAlightAttempt` and `onPassengerBoardAttempt` are additionally called).

- Movement to another space.

When a server script directly sets the position or direction of an entity that is controlled by a client, the CellApp treats that as a physics correction. A new position and direction (sometimes referred to as the *pose*) are forced down to the client, and no future position and direction updates are accepted until the correction is acknowledged. This feature can be very useful for teleporting a player in response to some action or event on the server. Notably, the methods `Entity.teleport`, `Entity.boardVehicle` and `Entity.alightVehicle` also adhere to this mechanism. Server-side teleports are the only way to move an entity between spaces.

While in most cases movement controllers would also result in downstream-forced positions, their use on client-controlled entities is neither recommended nor supported, since they continually set the position via a system intended for one-off adjustments.

10.4.1. Avoiding Y-axis rubber-banding.

Due to the manner in which physics validation occurs, if a top speed has been exceeded, the server will force a position update to the client with the last known valid position. This however has the unfortunate side effect of producing an entity which doesn't fall if the top speed has been exceeded in the Y-axis. Setting the `topSpeedY` to be higher than `topSpeed` will help in this situation, but eventually, the Y-velocity will be greater than `topSpeedY` due to acceleration due to gravity when falling for long periods.

In order to produce a work around for this, it is recommended to write a custom physics validator while setting a large value for `topSpeedY`. The custom physics validator could then perform its own validation and update the entity position with a decreasing Y-position prior to returning `false`, and the updated position would then be forced to the client.

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Chapter 11. Entities and the Universe

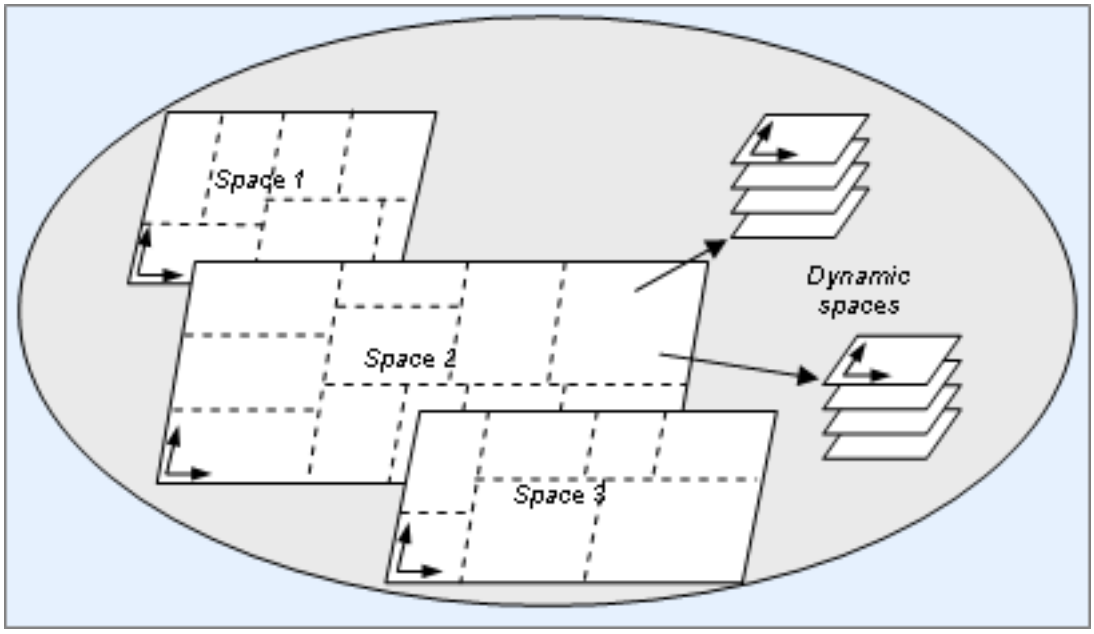
Entities in BigWorld are contained in the game universe. A universe is composed of spaces, which are composed of cells.

Each space can contain:

- Space Data for information that must be available to the entire space.
- Geometry to define where entities can move.
- Time of day, which is used by clients to determine day/night cycles.

11.1. Multiple Spaces

BigWorld supports having multiple separate geometric spaces in a universe. Each space can have a different set of geometry mapped into it, and a different set of entities existing within it. Each CellApp can handle multiple cells in different spaces.



Visualisation of spaces and division in cells (cell boundaries marked in dotted lines)

Spaces are usually created by creating an entity in a new space. For this reason, every space needs at least one entity and as such once a space has no entities, it will cease to exist.

A common design technique to make this management easier is to create an entity `Space` (usually named after the space's purpose, *e.g.*, `Mission`, or `Quest`). Such an entity will be created in a new space, and then be responsible for configuring that space for game play to begin. Players can then teleport into the new space to explore it, play their mission, etc.

The general structure of this kind of entity is the illustrated in the code fragments below:

- Base script:

```
class Space( BigWorld.Base ):
```

```
  def __init__( self ):
    # create our cell entity in a new space. self.onGetCell() will be
    # called when the cell entity is created.
    self.createInNewSpace()

  def onGetCell( self ):
    # create any predefined entities in the space
    # may want to use ResMgr to load details from an XML file

    # we want to make sure that each entity's createCellEntity()
    # method is passed the appropriate cell mailbox (this entity's
    # cell mailbox) so that it is created in the correct space
    # for example:
    BigWorld.createBase( "Monster", arguments, createOnCell=self.cell )
```

Example file <*res*>/scripts/base/Space.py

- **Cell script:**

```
class Space( BigWorld.Entity ):

  def __init__( self ):
    # Register our mailbox for getting the callback when the space
    # geometry finishes loading. You can choose any arbitrary string
    # as the key so long you can find this entry again.
    BigWorld.cellAppData[ 'SpaceLoader:' + str(self.spaceID) ] = self

    # Add the geometry mapping. This maps the set of .chunk files we
    # want into the space. BWPersonality.onAllSpaceGeometryLoaded will
    # be called when BigWorld finished loading the geometry.
    BigWorld.addSpaceGeometryMapping( self.spaceID, None,
      "geometry/path" )

  def onGeometryLoaded( self ):
    # we can now also teleport in any additional entities that already
    # existed in the world (we'd probably store a mailbox somewhere in
    # the construction sequence to make this possible)
    # see the cell entity teleport() method for details
    playerMB.teleport( self, position, direction )
```

Example file <*res*>/scripts/cell/Space.py

- **Cell personality script:**

```
def onAllSpaceGeometryLoaded( spaceID, isBootstrap, lastPath ):
  if (isBootstrap):
    # Find the registered loader and tell it to load the entities into
    # the space.
    loaderKey = 'SpaceLoader:' + str(spaceID)
    if BigWorld.cellAppData.has_key( loaderKey ):
      BigWorld.cellAppData[ loaderKey ].onGeometryLoaded();
```

Example file <*res*>/scripts/cell/BWPersonality.py

To create this entity, the code below would be written[1]:

[1] This entity creation would normally be initiated from a client side action such as a "Create Mission" user interface option, or from a player entering a dungeon portal.

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```
newSpace = BigWorld.createBaseAnywhere( "Space", ... )
```

Notice that there are four key steps in this piece of code:

1. Create the cell entity in a new space (in the `__init__` method).
2. When the cell entity is created, map in any geometry that the space contains.
3. Create any entities that are required to be in the world.
4. When the space geometry is loaded, bring any required players into the space.

It is likely that there will be management code specific to the style of space that is required (this code will be heavily dependant on your game's requirements). It is also possible to perform various steps between the cell and the base, depending on entity instantiation requirements.

When all entities in a space are removed, the space will be destroyed. Alternatively, any entity in the space can call the method `Entity.destroySpace` to destroy the current space the entity exists in. Each entity in the space will have its method `onSpaceGone` called before it is actually destroyed.

11.1.1. Spaces Pool

When your game requires multiple instances of a space (*e.g.*, a mission space), it is advantageous to create a pool of reusable space instance during game startup.

This mechanism removes the need of later having to load chunks on demand, as when players request to enter a space, an instance will be chosen from the pool. After players leave the space, you can move the space back to the pool for later usage. This mechanism can greatly speed up the game loading for players on the server.

11.2. Navigation System

The sub-sections below describe the features of the Navigation System.

11.2.1. Key Features

The key features of the system are:

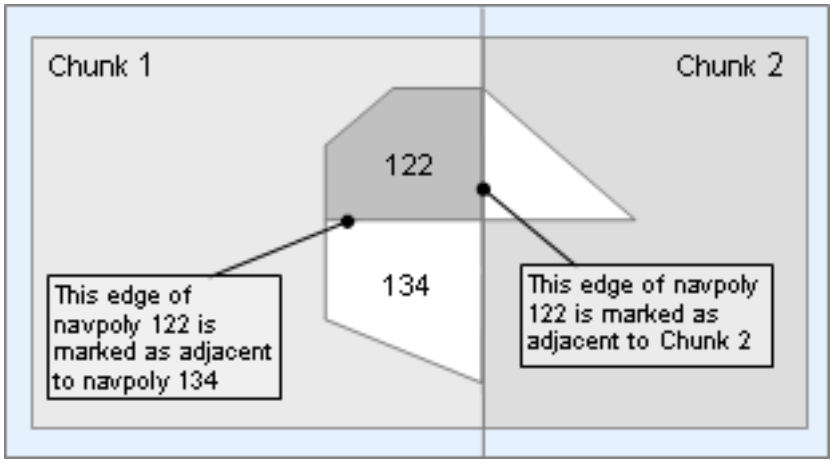
- Navigation of both indoor and outdoor chunks.
- Seamless transition between indoor and outdoor regions.
- Dynamic loading of navpoly graphs.
- Paths caching, for efficiency.

11.2.2. Navpoly Data Format

The world is broken up into chunks. Each chunk is a convex hull, and is uniquely identified by a chunk ID string, *e.g.*, `0000ffffo`.

For navigation purposes, each chunk is broken up into a set of convex polygonal prisms. Such a prism is known as navpoly, and is identified by an integer navpoly ID unique to a single chunk.

Each edge on a navpoly can be shared with the edge of an adjacent region. This means that movement between these two regions is allowed. Alternatively, an edge may be marked as being adjacent to a different chunk.



Navpoly edge demarcation

A navpoly also has a height associated with it. This is the maximum height of the navpoly region, such that the client can do a drop test from this Y value, and always end up on the bottom of the navpoly.

Vertices in the navpoly are defined in clockwise order, and have its XZ coordinates stored in the XY fields.

The third coordinate is used to store adjacency information for the edge formed between this vertex and the next. The value of this third coordinate is either the navpoly ID of the adjacent navpoly, or an encoding of an obstacle type. Edges on chunk boundaries are indicated by the presence of a separate tag for the adjacent chunk ID. In this case, the third vertex coordinate is not used.

The example file below illustrates this concept:

```
<navpoly>  230

  <minHeight>  11.662999  </minHeight>
  <height>    14.362000  </height>

  <vertex>     3.100000 88.099998  239.000000    </vertex> 1


  <vertex>    -0.900000 88.099998  0.000000
    <adjacentChunk>  FFFF0000o  </adjacentChunk> 2
  </vertex>

  <vertex>    -0.900000 94.599998  228.000000    </vertex>
  <vertex>     8.100000 94.599998  229.000000    </vertex>
  <vertex>     9.600000 94.599998 -2231.000000    </vertex> 3

</navpoly>
```

Example <*res*>/spaces/<*space*>/<*chunk_ID*>.chunk file - Navpoly demarcation format

1 'z' coordinate refers to adjacent navpoly 239
2 'z' coordinate unused due to reference to adjacent chunk `FFFF0000o`.
3 Negative 'z' coordinate encodes an obstacle type (half height, etc).

11.2.3. Script Interface

When an entity wants to navigate to a position, it uses the Python `Entity.navigate` script method, like the example below:

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```
self.controllerId = self.navigate( position, velocity, userTag, girth )
```

The parameters for the `navigate` script method are described below:

- ***`position`*** - The destination position.
- ***`velocity`*** - Movement velocity in metres per second.
- ***`userTag`*** - Integer value passed to the navigation callback.
- ***`girth`*** - Minimum width of the gap that the entity can squeeze through.

If there is no valid path to the destination, then navigate will fail, and throw a script exception. Otherwise, it will return a controller ID. This is a unique ID that can be used to cancel the movement request, like so:

```
self.cancel( self.controllerID )
```

When the movement is complete, the entity's `onNavigate` method will be called, with the `controllerId` and `userId` as arguments. At this stage, all resources related to the controller have been released, and there is no need to free them by calling `Entity.cancel`.

```
self.onNavigate( controllerId, userId )
```

11.2.4. Navigate

When the `Entity.navigate` script method is called, the server performs the following steps:

1. Resolve the `ChunkID` and `WaypointID` from the source location.
2. Resolve the `ChunkID` and `WaypointID` from the destination location.
3. If the `ChunkID`s are different, then perform a graph search on the chunk level. Otherwise, if the `WaypointID`s are different, then perform a graph search on the navpoly level. If both these tests fail, move in a straight line to the specified position.

11.2.5. Graph Searches

An A* search is used for both the chunk graph search and the navpoly graph search. The `ChunkState` and `WaypointState` classes both implement the interface required for an A* search, and are used to search the chunk and navpoly graphs respectively.

The chunk graph is searched by using the centre of each chunk for calculating distances.

Distances on the navpoly graph are calculated based on the actual path that would be taken through the navpolys.

Given a source location inside the navpoly, and a destination location outside the navpoly, the algorithm is as follows:

- Find the point where the direct line from source to destination would intersect the polygon border.
- If this point is on an edge that has an adjacency, move directly to the point of intersection.
- Otherwise, move to a vertex that has an adjacency, such that the angle between this path and the desired path is minimised.

This is a simple approach, and not always optimal, but works properly in most cases.

The `PathCache` class is used as a wrapper for performing both chunk and navpoly graph searches. It caches one path per entity, and also stores the current hop index within that path. Each time a graph search would take place, the `PathCache` checks if the goal is the same as the cached goal. If so, then the next state in the path is returned, and the hop index is incremented, if appropriate.

11.2.6. Auto-Generation of Navpoly Regions - The NavGen Utility

Based on terrain and other geometric information in the chunk files (named `<res>/spaces/<space>/<chunk_ID>.chunk`[2]), the NavGen utility creates the convex navpoly polygonal prisms in two phases:

1. It flood fills each chunk, using client physics rules.
2. It uses a BSP to recursively subdivide the space and form convex polygonal prisms.

It writes the results in the binary `.cdata` files[3].

The NavGen utility handles multiple vertical levels within a chunk (bridges, tunnels, etc...). It uses a multi-pass algorithm to analyse and describe the connectedness of such scenes.

NavGen's XML configuration file `<bwclient_source_folder>/../tools/misc/navgen_settings.xml` accounts for different entity profiles, such as their size and other physical properties. This is represented by the `girth` value. Multiple girths may be specified, in which case multiple navigation meshes will be generated and maintained. For each girth, different physical parameters may be set (*e.g.*, there is a flood fill parameter for the entity's height). A setting of 2.0 metres is good default for humanoid entities.

For more details, see the document Content Tools Reference Guide's chapter *NavGen*.

11.3. Time

We have seen how entities define how different pieces of a game can behave. Game play involves changing entities' states over time, and so it is important to have a good understanding of how time is managed in the BigWorld environment.

It helps to think about different types of time when discussing time in BigWorld. These types are discussed in the following sub-sections.

11.3.1. Real Time

Real Time is simply the time on a clock in the real world. Real time is used as the basis for defining the other types of time in BigWorld.

11.3.2. Server Time

On the server, game time is incremented in discrete units, based on the `<gameUpdateHertz>` configuration option in `<res>/server/bw.xml`[4].

The server keeps an integer counter that is incremented at this rate and whose initial value at server startup is `0`.

To calculate the server time in seconds, the following formula is used:

```
serverTime = serverTimestamp / gameUpdateHertz
```

[2] For details on this file's grammar, see the document File Grammar Guide's section *.chunk*.

[3] For details on the information held by this and other chunk files, see the document Client Programming Guide's section *Chunks* → "Implementation files". For details on `.cdata` files' grammar, see the document File Grammar Guide's section *.cdata*.

[4] For details, see the document Server Operations Guide's section *Server Configuration with bw.xml* → "General Configuration Options".

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This is approximately:

```
serverTime ~= currentRealTime - serverStartRealTime
```

Each client machine calculates a synchronised version of this time, available via the `BigWorld.serverTime` script method.

11.3.3. Game Time

Game Time is the time sensed by the players in the game world.

A massively online persistent game usually has virtual days and months in its virtual world. You might want to run one game world hour for every hour of Real Time, for example. In order to support this, BigWorld has a standard piece of space data used to calculate the time of day[5].

This space data records the following numbers:

- **`initialTimeOfDay`** - Game Time when server started.
- **`gameSecondsPerSecond`** - Conversion factor, from Server Time update rate to Real Time.

They are used together to define Game Time as:

```
gameTimeOfDay = ( serverTime - initialTimeOfDay ) * gameSecondsPerSecond
```

To modify game time for an entire space a CellApp Python method called `BigWorld.setSpaceTimeOfDay` can be used. This method takes three parameters as follows:

- ***`spaceID`*** - The ID of the space which should be effected.
- ***`initialTimeOfDay`*** - The time of day at server startup.
- ***`gameSecondsPerSecond`*** - The number of game seconds that pass for each real time second.

To modify only client side visualisation based on time, refer to the Client Python method `BigWorld.spaceTimeOfDay`.

11.4. Initialisation: Personality script, eload, and runscript

By default, when the server is started, a single *default* space is created, containing no entities and no geometry. In order to make a game interesting, scripts must populate this space, and possibly create other spaces to also populate. While the server is running, you might wish to run specialist scripts to change properties of elements within the world. These tasks can be completed using the personality script, and two server side tools: eload and runscript.

The personality script can contain a Python function to be executed on every BaseApp right after there is an available CellApp running. In this way, it is guaranteed that you can create both cell and base entities from the script.

The script to be executed is specified in the file `<res>/server/bw.xml`, as in the example below:

```
<root>
  ...
  <personality> personalityscript </personality>
  ...
</root>
```

[5] For more details on space data, see “Space Data” on page 97 .

Example file <*res*>/server/bw.xml - Declaring the personality script

The corresponding file (following the example above would be `personalityscript.py`) is placed in the directory `<res>/scripts/base`, to be executed at the appropriate time.

If a personality script is not defined, then the default filename `BWPersonality.py` is used.

The method `onBaseAppReady` in the personality script is called by the BaseApp. The method receives one Boolean argument, whose values are defined below:

- **`True`** - If the BaseApp is the first one ready in the server clusters.
- **`False`** - If the BaseApp is not the first ready in the cluster.

The personality script can call any BigWorld module method, and it is the recommended point to perform the following:

- Add geometry to the space by calling `addSpaceGeometryMapping` from a cell entity.
- Initialise the game time by calling method `setSpaceTimeOfDay` from a cell entity. For more details, see “Game Time” on page 93 .
- Initialise any custom space data. For more details, see “Space Data” on page 97 .
- Populate the world by creating entities.

During the execution of the personality script functions, the BaseApp cannot respond to messages received from other server components. A time-consuming personality script is likely to timeout the BaseApp from the server clusters. It is recommended to spread the entity creation in a timely manner for a smooth and robust startup.

The example is illustrated below, with code on the personality, base, and client scripts.

- **In the personality script:**

```
...
def onBaseAppReady( bool isBootStrap ):
  if isBootStrap:
    BigWorld.createBase( "SpaceManager", {}, {} )
    BigWorld.createBase( "EntityLoaderManager", {}, {} )
  # every BaseApp needs an EntityLoader
  BigWorld.createBase( "EntityLoader", {}, {} )
...
```

Example personality script <*res*>/scripts/base/<personality_script_name>.py

- **On the BaseApp:**

```
class SpaceManager( BigWorld.Base ):
  def __init__( self ):
    # create the cell entity in a new space
    self.createInNewSpace( (0,0,0), (0,0,0), None )

class EntityLoaderManager( BigWorld.Base ):
  def __init__( self ):
    # register globally under a well-known name (ELM for example)
    # so the EntityLoaders can register with me
    self.registerGlobally( "ELM", onRegister )
    # add a timer that calls back every 1 second.
    # User data is 999 (only for identification purpose)
```


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```
    self.addTimer( 1, 1, 999 )

  def onRegister( self, succeeded ):
    # callback from registerGlobally(). Argument succeeded should always
    # be True there is only one EntityLoaderManager in whole system
    if not succeeded:
      # should not be possible, try re-register
      self.registerGlobally( "ELM", onRegister )

  def registerLoader( self, entityLoader ):
    # append the mailbox of an entityLoader into our list
    # might have to verify it is not re-registered though
    self.entityLoaderList.append( entityLoader )

  def onTimer( self, timerId, userData ):
    if userData == 999:
      # distribute entity creation tasks to every registered
      # EntityLoader in a load spreading manner
      for i in range( len( self.entityLoaderList ) ):
        # prepare the argument for entity creation
        args = ...
        self.entityLoaderList[i].createEntities( args )
      if allJobFinished:
        # remove the timer if not required any more
        delTimer( timerId )

class EntityLoader( BigWorld.Base ):
  def __init__( self ):
    self.registerWithELM()

  def registerWithELM():
    if BigWorld.globalBases.has_key( "ELM" ):
      # if EntityLoaderManager is available register with it now
      elm = BigWorld.globalBases["ELM"]
      elm.registerLoader( self )
    else:
      # otherwise wait a bit
      self.addTimer( 1 )

  def onTimer( self, timerId, userData ):
    # retry registering
    self.registerWithELM()

  def createEntities( self, args ):
    # create the entities according to the arguments
```

Example file <*res*>/scripts/base/SpaceManager.py

- **On the CellApp:**

```
class SpaceManager( BigWorld.Entity ):
  def __init__( self ):
    # add the geometry mapping
    # this maps the set of .chunk files we want into the space
    BigWorld.addSpaceGeometryMapping( self.spaceID, None, "geometry/path" )
```

Example file <*res*>/scripts/cell/SpaceManager.py

For details on `eload` and `runscript`, see the document Server Operations Guide's section Admin Tools → Miscellaneous Command-line Tools.

11.5. Global Data

BigWorld offers several mechanisms for distributing *global* data to its components. Most of these mechanisms also offer callbacks when a particular piece of global data is modified, effectively turning them into global event distribution mechanisms as well.

As with most programming environments, global data should be treated with care, due to the challenges they pose to code maintenance. In a distributed system like BigWorld, globals should be used even more sparingly, because of the performance impact of data distribution, as well as the risk of race conditions.

11.5.1. `globalData`, `baseAppData` and `cellAppData`

BigWorld offers three Python dictionaries that are replicated across BigWorld components. They differ in their scope of replication:

- **`BigWorld.globalData`** - Replicated on all BaseApps and CellApps.
- **`BigWorld.baseAppData`** - Replicated on all BaseApps.
- **`BigWorld.cellAppData`** - Replicated on all CellApps.

The keys and values must be pickle-able Python objects. The value type can be any pickle-able Python object. If the value is a BigWorld entity, then it is converted to a mailbox on components where the entity does not currently reside.

The following callbacks are invoked when items in the dictionary are modified:

Global Data	Added or modified	Deleted
`baseAppData`	`BWPersonality.onBaseAppData`	`BWPersonality.onDelBaseAppData`
`cellAppData`	`BWPersonality.onCellAppData`	`BWPersonality.onDelCellAppData`
`globalData`	`BWPersonality onGlobalData`	`BWPersonality onDelGlobalData`

BigWorld only detects an item change if it is assigned to a different object, not when part of the object is changed. For example:

```
BigWorld.globalData[ "list" ] = [1, 2, 3]   # addition is detected
BigWorld.globalData[ "list" ][1] = 7        # modification not detected
BigWorld.globalData[ "list" ] = [3, 4, 5]   # modification is detected
```

If the modification is not detected, then the change will not replicated to other components, resulting in inconsistency between the local and remote copies.

Each value object is pickled individually. This results in the value being a copy of the original. For example:

```
drinks = [ "juice", "wine" ]
# BigWorld.globalData[ "fridge" ] will have its own copy of [ "juice","wine" ]
BigWorld.globalData[ "fridge" ] = drinks
# BigWorld.globalData[ "cupboard" ] will have its own copy of [ "juice","wine"
 ]
BigWorld.globalData[ "cupboard" ] = drinks
```

If multiple components concurrently modify the same item in the dictionary, then a central authority will determine the order of modifications. For `globalData` and `cellAppData`, the authority is CellAppMgr; for `baseAppData`, the authority is BaseAppMgr.

Callbacks for the modifications will be called in the order determined by the authority. In the components where the modifications took place, the dictionary item will temporarily have the value of the local

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modification before it is overridden by the value determined by the authority. Therefore, it is recommended that any actions that should take place after a change to global data be placed in the callback functions instead of inline with the code that changes the value of global data. For example:

```
def someFunction( ):
  BigWorld.globalData[ "mode" ] = 3
  # Should not put actions for mode 3 here. Otherwise there is a risk
  # that it will be performed in a different order on different
  # components

# In BWPersonality.py
def onGlobalData( key, value ):
  if ((key == "mode") and (value == 3)):
    # Do actions for mode 3
```

In addition to the components where `globalData`, `baseAppData` and `cellAppData` are replicated, the dictionaries are also backed up to the following locations:

Global Data	BaseAppMgr	CellAppMgr	Database
`baseAppData`	✓	✗	✗
`cellAppData`	✗	✓	✗
`globalData`	✓	✓	✗

The backup copies are used in the case of a component failure. However, since the dictionaries are never backed up to the database, in the event of entire server failure, these dictionaries will be empty after disaster recovery has completed.

11.6. Space Data

Space data is a means to distribute global data across the cell and client. It can be used for data that should be transmitted to the client, but does not fit in the entity structure. Such examples, which are built into BigWorld itself, include:

- **Time of day** - Two floats containing data that allows BigWorld to translate Server Time to Game Time.
- **Space geometry** - String describing which geometries are mapped into a space.

Space data consists of a 16-bit integer index, and a string. By packing various types into a string, it can represent any application-defined data type.

A piece of space data can be set by calling the method `BigWorld.setSpaceData` on the cell.

The function takes the parameters described below:

Parameter	Description
`spaceID`	The space in which to set the space data. Each space has its own unique set of space data, which is never shared between spaces.
`key`	A 16-bit integer index identifying which piece of space data to set. All indices less than 256 are reserved for internal BigWorld usage, so games developers must choose values greater than or equal to 256 (`SPACE_DATA_FIRST_USER_KEY`). For keys less than 16,384 (`SPACE_DATA_FIRST_CELL_ONLY_KEY`), space data is automatically sent to clients.
`value`	A string to set as the current space data value for this key.

When space data is set, a space data entry ID is returned. The entry ID and the `key` can be used to retrieve the space data using the `BigWorld.getSpaceData` method. Entry ID is required because BigWorld supports having multiple space data entries with the same key using the method `BigWorld.addSpaceData`. All entries for a particular key can be retrieved using `BigWorld.getSpaceDataForKey`.

For keys that should never have more than one entry, the method `BigWorld.getSpaceDataFirstForKey` can be used to retrieve a space data entry with only the key. The method returns the first entry with the specified key. The ordering of entries is guaranteed to be the same across all CellApps.

When multiple CellApps simultaneously call `BigWorld.setSpaceData` with the same key, there is a small possibility that both entries are kept by BigWorld. In this case, `BigWorld.getSpaceDataForKey` would return many entries. But since `>BigWorld.getSpaceDataFirstForKey` is more commonly used for keys that should have only one entry, the situation is usually resolved automatically.

Whenever a new space data value is added, `onSpaceData` is called on the personality script. For more details, see the CellApp Python API documentation's entry **Main Page → Cell → BW Personality → Functions → `onSpaceData`**.

Space data is backed up to the CellAppMgr as well as the database. Space data is preserved in all failure scenarios handled by the BigWorld server.

11.7. Global Bases

BigWorld provides a registry of base entity mailboxes that is replicated on all BaseApps. Base entities represented in this registry are referred to as global bases, and their mailbox can be retrieved by name on all BaseApps.

In order to give a name in the global registry to a base entity, you can call its method `registerGlobally`[6]. This method takes the following parameters:

- A name for the base entity to register as.
- A callback function to be called when the registration is complete or has failed. The callback function is called with a single Boolean parameter indicating if the registration was successful.

The method `registerGlobally` can be called multiple times on a single entity with different names. It is not allowed to register two different entities (or the same entity twice) with the same name.

The BaseApp contains the object `BigWorld.globalBases`, which emulates a read-only Python dictionary that provides information on global bases.

The object `BigWorld.globalBases` can be used as illustrated below:

```
print "The main mission entity is", BigWorld.globalBases["MainMission"]
print "There are", len( BigWorld.globalBases ), "global bases."
```

Using the BaseApp's object `BigWorld.globalBases` to retrieve information on global bases

Things to consider when using global bases include:

- Remember that global bases are not actually distributed themselves, only their mailboxes are. You may not want these entities to be accessed frequently by many different entities, as it could affect the scalability as more players log in.
- Often the game design will require an interaction to locate many entities that might otherwise be considered global. For example, perhaps a conversation with a faction leader is required to join that faction, and as such might remove the need to declare that an entity is global.

[6] You can remove an entity from the global bases registry with its method `deregisterGlobally`.

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Chapter 12. XML Data File Access

12.1. ResMgr.DataSection

Server component scripting can access custom data stored in XML files. These would typically be used to store game data resources, for example, anything from gameplay tables to configuration data. The data is stored in an XML hierarchy, accessible by traversing the tree defined in the each XML file.

12.2. Accessing Data

Suppose that a data file is defined as in the example below:

```
<root>
   <character>     Sir Manfred
      <description> White knight                          </description>
      <modelName>   sets/main/characters/knight.model     </modelName>
      <race>        human                                 </race>
      <gender>      0                                     </gender>
   </character>

   <character>     Sofia
      <description> Evil queen                            </description>
      <modelName>   sets/main/characters/queen.model      </modelName>
      <race>        undead                                </race>
      <gender>      1                                     </gender>

      <slaves>
         <character>     Underling
           <description> Hapless underling                      </description>
           <modelName>   sets/main/characters/guard.model       </modelName>
           <race>        undead                                 </race>
           <gender>      1                                       </gender>
         </character>

         <character>      Servant
            <description> Unpaid slave                         </description>
            <modelName>   sets/main/characters/servant.model   </modelName>
            <race>        undead                               </race>
            <gender>      1                                    </gender>
         </character>
      </slaves>
   </character>
</root>
```

Example XML file - *<res>*/scripts/data/Characters.xml

You can access this data by creating a new `DataSection` using the `ResMgr.openSection` method. The path argument used is relative to the resources path. This is illustrated in the example below:

```
ds = ResMgr.openSection( 'scripts/data/Characters.xml' )

# this will retrieve "Sir Manfred"
ds.child( 0 ).asString

# this will retrieve "White knight"
ds.child( 0 )['description'].asString

# this will retrieve 1
```

```
ds.child( 0 )['gender'].asInt
```

Reading an XML data file

12.2.1. Opening a Section Within an XML File

You can access a section within the XML file by adding the name of the section to the end of the path given to ResMgr.openSection:

```
dsChild = ResMgr.openSection(
  'scripts/data/Characters.xml/character' )
```

Reading an XML data file - Accessing a specific section

If there are multiple elements with the same under the root element, then the first one is returned.

12.3. Data Types

The available data types are:

Data type	Accessed by
64-bit floating-point numbers	`.asDouble`
64-bit integers	`.asInt64`
Data blob	`.asBlob`
Floating-point numbers	`.asFloat`
Integers	`.asInt`
Matrix	`.asMatrix`
Raw binary representation of the XML node	`.asBinary`
String	`.asString`
Vector2	`.asVector2`
Vector3	`.asVector3`
Vector4	`.asVector4`
Wide strings	`.asWideString`

For more details, see the Client Python API documentation's entry **Class List → DataSection**.

12.4. Writing Data

You can write to properties by referencing the appropriate `.as<`*`data type`*`>` property, then saving the XML file.

Note

This feature is for use only on server tools, and you should avoid using it in game scripts.

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An important limitation to be aware of is that it is only possible to save a `DataSection` that has been opened by reference to an XML document. It is not possible to directly save a section that is retrieved by a path to a sub-element within a file.

For example, the code below will *not* work:

```
# this will not work, throws IOError
dsChild = ResMgr.openSection( 'scripts/data/Characters.xml/character' )
dsChild.asString = "Sir Lancelot"
dsChild.save()
```

Example of incorrect procedure for writing to XML

The code excerpt below, on the other, will work:

```
# this will work
dsRoot = ResMgr.openSection( 'scripts/data/Characters.xml' )
dsChild = dsRoot.child( 0 )
dsChild.asString = "Sir Lancelot"
dsRoot.save()
```

Example of correct procedure for writing to XML

You can also add or remove child elements from each data section:

```
# get the document data section
dsRoot = ResMgr.openSection( 'scripts/data/Characters.xml' )

# this will delete the first character
dsRoot.deleteSection( 'character' )

# create a new character, which is appended to the top-level
newChild = dsRoot.createSection( 'character' )
newChild.asString = "King Arthur"

newChild.createSection( 'description' )
newChild.createSection( 'modelName' )
newChild.createSection( 'race' )
newChild.createSection( 'gender' )
newChild.createSection( 'slaves' )

newChild['description'].asString = "The King of Camelot"
newChild['modelName'].asString = 'sets/main/character/knight.model'
newChild['race'].asString = 'human'
newChild['gender'].asInt = 0
dsRoot.save()
```

Deleting sections and adding new ones

Running the code excerpt below, and assuming a `Characters.xml` as described in “Accessing Data” on page 99, the result will be the file below:

```
<root>
   <character>      Sofia
      <description> Evil queen                        </description>
      <modelName>   sets/main/characters/queen.model </modelName>
      <race>        undead                            </race>
```

```
      <gender>      1                                 </gender>

      <slaves>
         <character>      Underling
            <description> Hapless underling                   </description>
            <modelName>   sets/main/characters/guard.model    </modelName>
            <race>        undead                              </race>
            <gender>      1                                   </gender>
         </character>

         <character>      Servant
            <description> Unpaid slave                        </description>
            <modelName>   sets/main/characters/servant.model  </modelName>
            <race>        undead                              </race>
            <gender>      1                                   </gender>
         </character>
      </slaves>
   </character>


   <character>       King Arthur
      <description>  The King of Camelot               </description>
      <modelName>    sets/main/character/knight.model  </modelName>
      <race>         human                             </race>
      <gender>       0                                 </gender>
      <slaves>                                         </slaves>
   </character>

</root>
```

Resulting <*res*>/scripts/data/Characters.xml

12.5. Performance Issues

Accessing the XML files on disk can potentially halt game processing. This can occur from disk I/O and parsing of the resulting data. This halt to processing can occur for both reading as well as writing of XML files and should be avoided as much as possible.

Due to the adverse impact this can cause to game development and resulting behaviour, a separate document has been written to address these issues. For more details please refer to the document How To Avoid Files Being Loaded in the Main Thread.

12.6. API Reference

`ResMgr` documents the `DataSection`'s methods, and can be found in the BaseApp Python API documentation, CellApp Python API documentation, and Client Python API documentation.

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Chapter 13. Fault Tolerance

13.1. CellApp Fault Tolerance

13.1.1. Overview

Periodically, a complete copy of each cell entity is backed up on the base entity. Only cell entities with an associated base entity are fault tolerant. The CellApp backup period specifies how often cell entities are backed up to their base entities, and is specified in the `bw.xml` option `<cellApp/backupPeriod>`.

Should a CellApp process become unavailable, the real entities located on the cells residing on that process will be restored by their corresponding base entities to other CellApps. The state of the cell data of the restored cell entities is the same state as was given from the most recent backup from the cell entity to the base entity.

13.1.2. Restoration process

The CellApp restoration process typically follows these steps:

1. A CellApp process becomes unavailable.

2. Base entities that have cell entities on the now unavailable CellApp process restore their corresponding real entities to other CellApps.

3. Restored cell entities have the `onRestore`() callback called on them. Because the restored cell data is taken from the last time the cell entity backed up to the base, this copy can be up to twice the backup period. This callback should check that the entity's properties are in a consistent state.

4. For player cell entities, their corresponding client-side player entities have the `onRestore`() callback called on them.

The callback `onRestore`() is invoked on the cell entity to inform it that it is being restored.

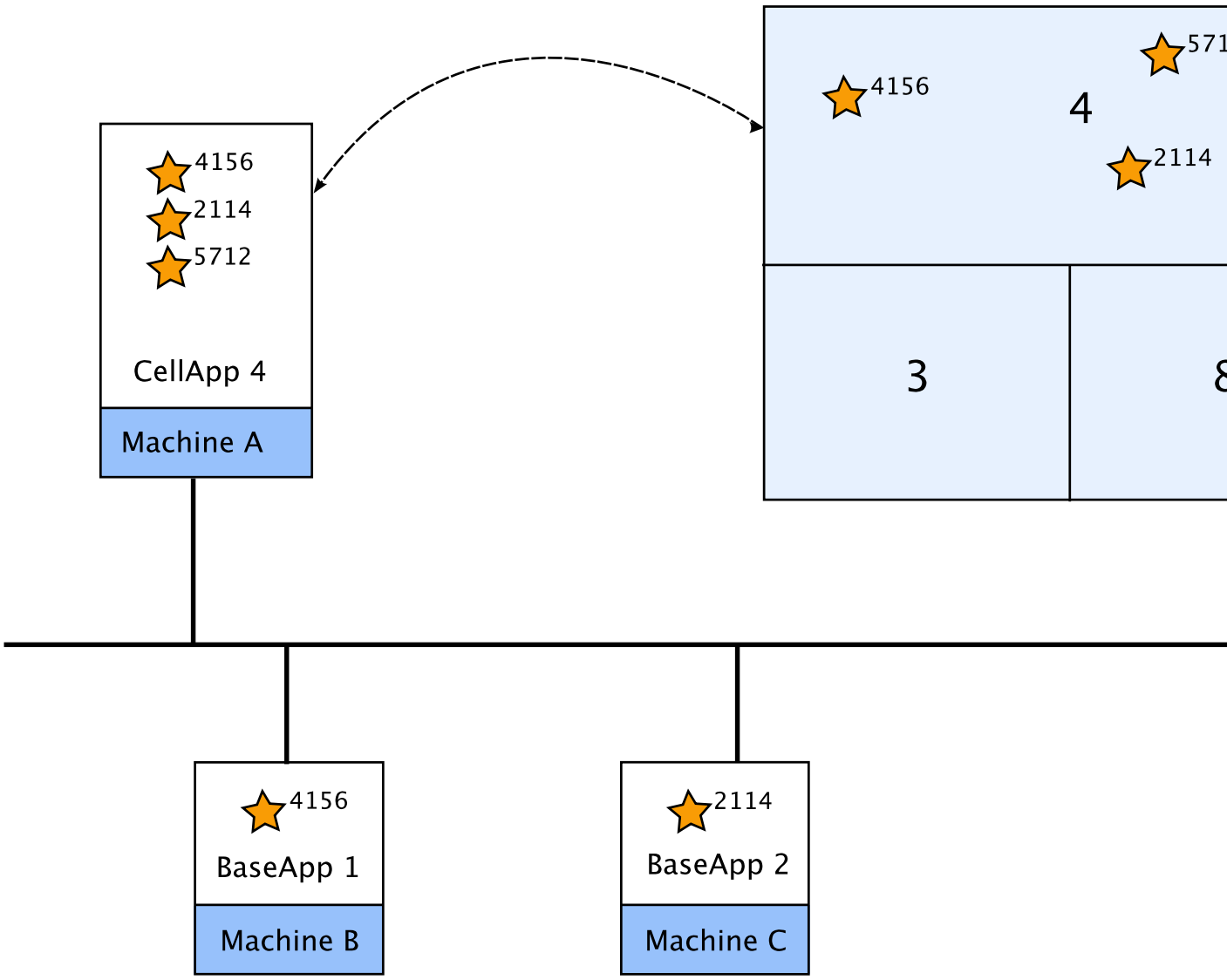
The code fragment below illustrates its implementation on the cell entity:

```
class SomeEntity( BigWorld.Entity ):
  ...
  def __init__( self ):
    # set up initial property values
  ...
  def onRestore( self ):
    # check that property values are consistent, and
    # perform any cleanups that need to occur
  ...
```

Example file `<res>/scripts/cell/SomeEntity.py`

13.1.3. Example

Figure . CellApp Fault Tolerance Example



The above diagram shows a space divided into three cells, the top cell residing on CellApp 4, the bottom-left cell residing on CellApp 3 (not shown) and the bottom-right cell residing on CellApp 8 (not shown). In the cell that CellApp 4 has in this space, it has the cell entities with IDs 4156, 5712 and 2114, all within the same spatial region. The entities 4156 and 2114 have corresponding base entities that reside on BaseApp 1 and 2 respectively. Entity 5712 does not have a base entity, and is a cell-only entity.

Cell entities back up their data to their corresponding base entities. So in this example, entities 4156 and 2114 send a copy of themselves to their corresponding base entities. The rate at which they do this can be configured by changing the backup period, using the `bw.xml` option `<cellApp/backupPeriod>` (see the "CellApp Configuration Options" for more details). When a single CellApp goes down, cell entities are restored from the backup data sent to their base entities. Any cell entities that do not have corresponding base entities will not have been backed up, and so will not be restored.

If CellApp 4 was to go down, the cell entities for 4156 and 2114 will be restored onto other CellApps from their base entities. Entity 5712 will not be restored, as it has no corresponding base entity.

It is important to note that when restoring cell entities, the cell data that is used will be whatever data was present at the time of the last cell entity backup. Thus, any modification to the cell entity data since the last

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backup is lost, and the state of that cell entity may be inconsistent when it is restored. For example, a backup of a cell entity may be made in the middle of a multi-step transaction. The script callback `Entity.onRestore()` can be used to check the state of outstanding transactions, and the decision to either roll them back or continue them can be made in script.

13.2. BaseApp Fault Tolerance

With BaseApp fault tolerance, BaseApps back up the base entity data and cell backup data of all their base entities to other BaseApp processes periodically:

- **Distributed BaseApp Backup**

  Each BaseApp backs up its entities on other (more than one) regular BaseApps.

- **Non-distributed BaseApp Backup**

  Regular BaseApps back up all their entities on dedicated Backup BaseApps.

Note

As of BigWorld 1.9, non-distributed BaseApp is deprecated. It is planned that support for this feature will be removed in BigWorld 2.0.
BigWorld recommends the Distributed BaseApp Backup method, for the following reasons:

- No need for dedicated Backup BaseApps.
- Backup load is distributed over a period of time.
- No need for IP switching, which might not be allowed by operating system and/or router. This also makes cluster management easier.

Should the primary BaseApp become unavailable, then all its entities are restored from the backup process. In this case, the BaseApp invokes the callback `onRestore` on the base or proxy entity, in a process similar to the one for CellApp restoration. This callback should ensure that all properties on the entity are in a consistent state.

It should be noted that in the Distributed BaseApp Backup method, entities that were on the same BaseApp before its death, might be restored to different BaseApps. Care should be taken when writing scripts, to avoid assumptions that a Base entity is local. When performing an entity backup, Base entity properties are streamed using their description in the definition file (if there is one). For properties that are not specified in the definition file, these are pickled. Each entity is backed up individually, so if two entities refer to the same object, on restoration they will likely each have a copy of that object. An option is available to prevent properties not specified in the definition file from being backed up. To disable backing up undefined properties set the `bw.xml` option `<baseApp/backUpUndefinedProperties>` to `false`. For more information on this option refer to the Server Operations Guide section “BaseApp Configuration Options”.

For more details regarding Fault Tolerance, see the document Server Operations Guide's chapter Fault Tolerance, and the document Server Overview's section Server Components → BaseApp → Fault tolerance.

The backup method is determined by `bw.xml`'s configuration option `baseAppMgr/useNewStyleBackup`. For details, see the document Server Operations Guide's section Software Configuration with bw.xml → BaseAppMgr configuration options.

Chapter 14. Disaster Recovery

BigWorld's fault tolerance ensures that the server continues to operate if a single process is lost. The server also provides a second level of fault tolerance known as disaster recovery. The server's state can be written periodically to the database. In the event of entire server failure, the server can be restarted using this information.

The rate of this archiving is specified in the file `<res>/server/bw.xml` by the configuration options `<baseApp/archivePeriod>` and `<cellAppMgr/archivePeriod>`. For more details on these options, see the document Server Operations Guide's chapter *Server Configuration with* `bw.xml`'s sections "BaseApp Configuration Options" and "CellAppMgr Configuration Options".

The CellAppMgr process is responsible for writing to the database the spaces, their data, and the game time.

Entities with a valid database entry are also periodically archived (indicated by a non-zero `databaseID` on the base entity). To write an entity to the database, thus enabling its archiving, call the method `writeToDB`() on the base or cell entity.

Each time an entity is archived, its callback `onWriteToDB`() is invoked.

Starting a server with this archived information is the same as starting the server after a controlled shutdown. For more details, see *Controlled Startup and Shutdown* on page 107 .

For more details regarding Disaster Recovery, see the document Server Operations Guide's chapter "Disaster Recovery".

Chapter 15. Controlled Startup and Shutdown

There may be times when the server needs to be shut down and later restarted in a similar state. This chapter describes the script-related details of this scenario.

For more details, see the document Server Operations Guide's chapter *Controlled Startup and Shutdown*.

15.1. Controlled Shutdown

The process of controlled shutdown is described in the list below:

1. `USR1` signal is received by LoginApp processes.
2. The LoginApp processes shut down immediately.
3. The CellAppMgr receives a message to schedule the shutdown (in game time).
4. The CellAppMgr sends a message to the other processes informing them when the shutdown is scheduled for.
5. The callback `onCellAppShuttingDown` on the CellApp personality script is invoked.

   The personality scripts on this step and the next should perform the appropriate finishing tasks, like ending long running tasks such as combats or trades, informing the players, and stopping new long running tasks from starting.
6. The callback `onBaseAppShuttingDown` on the BaseApp personality script is invoked.
7. Once these callbacks have been executed, calls to method `BigWorld.isShuttingDown` will return `True`.
8. The other server processes (CellApps, BaseAppMgr, BaseApps, Backup BaseApps, DBMgr, Reviver) do not stop immediately, instead performing any finishing tasks.

   This delay can be specified in the file `res/server/bw.xml` by using the configuration option `<shuttingDownDelay>`. For more details on this option, see the document Server Operations Guide's section Software Configuration with `bw.xml` → General configuration options.
9. Shutdown game time is reached.
10. Game stops running, but the processes not.

    This means that the game time is no longer incremented, and no game object is ticked.
11. When ready to shut down, CellAppMgr writes the spaces, their data, and the game time to the database.
12. This step takes place in parallel with step **11**.

    Each BaseApp performs the following steps:

    - Receives a message to disconnect any connected clients.
    - Invokes the callback `onBaseAppShutDown` with an argument of `0` before disconnecting the clients.

      For each disconnected client, the proxy's callback `onClientDeath` is invoked.
    - Invokes the callback `onBaseAppShutDown` with an argument of `1`, before writing to the database each entity with a database entry.
    - Invokes the callback `onBaseAppShutDown` with an argument of `2`.

13.All server process shut down.

15.2. Controlled Startup

When starting up, the DBMgr initially waits until all components are ready. A minimum number of BaseApp and CellApp processes can be specified in `bw.xml` via the options `<desiredBaseApps>` and `<desiredCellApps>`[1]. Once ready, the DBMgr loads the spaces and their data back into the system.

Entities stored from a previous session are then loaded into the system by creating the base entities. The script function `BigWorld.hasStarted` will return `False` during this stage. This can be handy for implementing different behaviour in the method `__init__` of restored entities.

It is up to the script to create the cell entity, if desired. Creating a cell entity during startup is often different from doing so during other times. Usually the method `Base.createCellEntity` is called with a cell entity mailbox to indicate the entity's space. But during startup, the entity's space ID is restored and set in the `Base.cellData` map. The base entity script may use this by calling the method `Base.createCellEntity` with no arguments.

Once the server is ready to start running, the callbacks `onBaseAppReady` and `onCellAppReady` from the personality script are called on the BaseApps and CellApps, respectively.

The game recovery function can be disabled by setting the `<dbMgr/clearRecoveryData>`[2] configuration option to `true`. When game recovery is disabled, the game is restarted with a single default space with no entities. For information on how to re-populate the game, see “Initialisation: Personality script, eload, and runscript” on page 93 .

[1] For details, see the document Server Operations Guide's section *Server Configuration with `bw.xml`* → “General Configuration Options”.

[2] For details, see the document Server Operations Guide's section *Server Configuration with `bw.xml`* → “DBMgr Configuration Options”.

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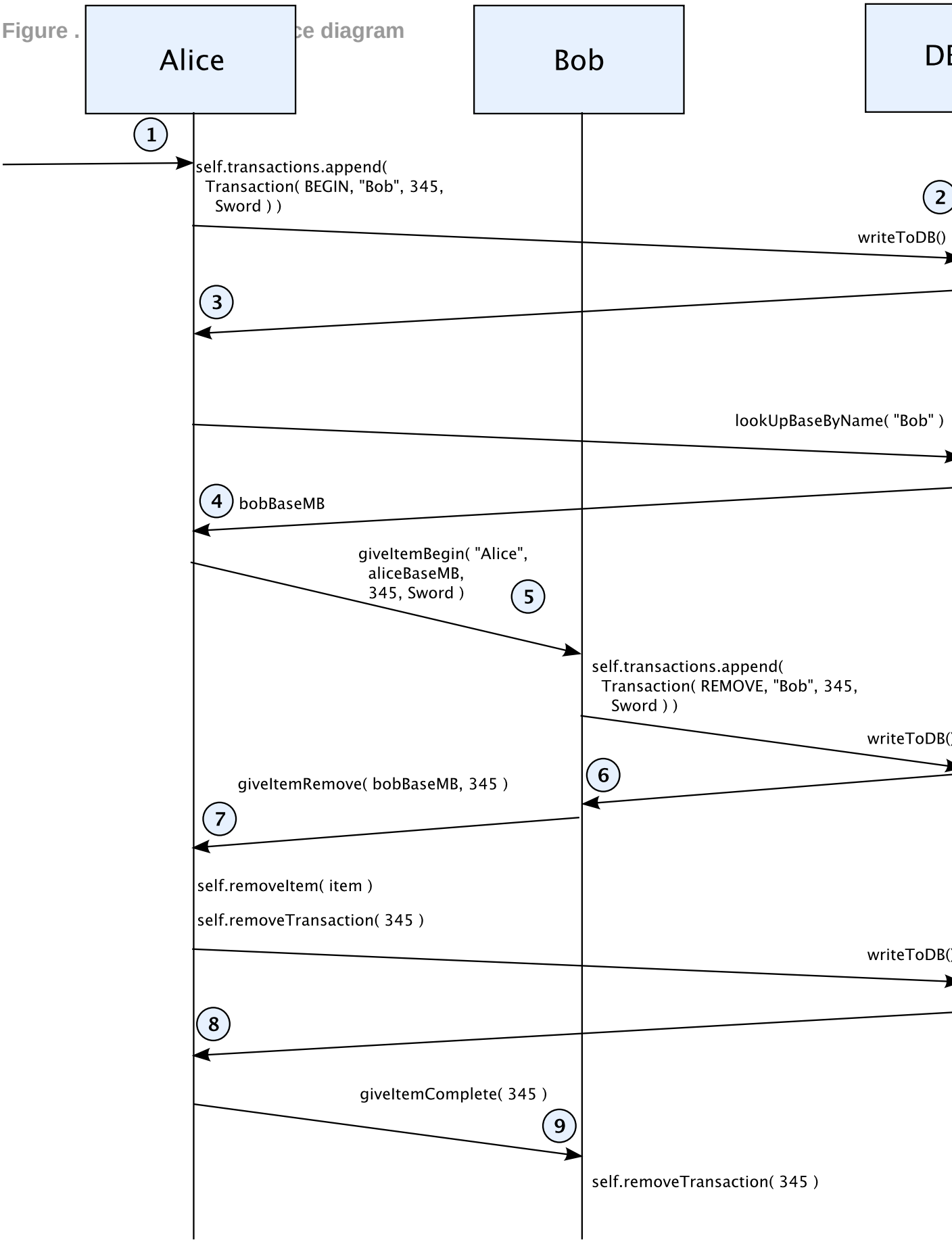
Chapter 16. Transactions and Handling Fault Tolerance and Disaster Recovery

We illustrate the previous chapters' guidelines with respect to handling fault tolerance and disaster recovery mechanisms in BigWorld by providing an example involving the use of transactions and how to make them work with fault tolerance and disaster recovery mechanisms.

16.1. Transaction logic

We give here an example of a trading transaction for transferring an item between two player entities.

Figure . ce diagram



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The transaction logic between the two player entities Alice and Bob is as follows:

1. Alice and Bob are within each other's Area of Interest (AoI). Alice's client informs her base entity that she would like to give Bob a Sword item.

   Alice's base entity is passed the player name of Bob as part of the request from the client, along with the representation of the Sword item within Alice's inventory.

   Alice's base entity adds an entry into her transaction list. This entry contains a unique transaction ID that identifies this transaction, Bob's player name, the state of the transaction (set to a symbolic constant called `BEGIN`), and the item in Alice's inventory.

   Alice's base entity removes the Sword from Alice's inventory.

   Alice requests a write to the database.

2. When the write to the database calls back, it indicates whether the write was successful or not.

   If it was not successful, then there is a problem with the database, and the transaction is aborted (a message is sent back to the client informing Alice of this situation), and the Sword is added back to Alice's inventory.

   Otherwise, if the write to the database was successful, the transaction action starts with Alice's base entity requesting an entity base mailbox lookup based on the player name, via the `BigWorld.lookUpBaseByName()` method, and registers a callback to a functor containing the transaction ID.

3. Alice's base entity gets notification with the base mailbox of Bob.

   If Bob's base entity can't be found, the transaction is aborted by removing the transaction entry from the transaction list, adding the Sword back to Alice's inventory, informing Alice's client and calling another `writeToDB()`.

   Otherwise, Alice's base entity calls a method on Bob's base mailbox and requesting that it add the Sword item to his inventory. We pass the item, transaction ID, Alice's player name and a mailbox back to Alice's base entity.

4. Bob's base entity adds the Sword item to its inventory (but marks it as unusable by Bob's client for the moment).

   Bob's base entity adds an entry into its transaction list, with Alice's player name, the state of the transaction set to the symbolic constant `REMOVE`, and the same transaction ID that was passed in from Alice.

   Bob's base entity then starts a write to the database, registering a callback to a functor object that holds Alice's base entity mailbox and the transaction ID.

5. Bob's base entity is called back with the result of the database write.

   If it was unsuccessful, Bob should remove the sword from his inventory as well as the transaction entry in the transaction list (the transaction ID is stored in the functor callback).

   If the write was successful, the item should be marked as usable for Bob's client.

   Whether or not the database write was successful, Bob's base entity informs Alice of the success of the database write through her base mailbox that is supplied through the functor callback. Bob passes in the success flag, a mailbox to Bob's base entity and the transaction ID.

6. Alice's base entity receives the result of the transaction from Bob's side.

   Alice removes the transaction entry from her transaction list.

If Bob indicated that the transaction was unsuccessful, Alice re-adds the item back to her inventory informs the client of the trading failure.

Alice writes to the database, and registers a callback to a functor that holds Bob's base mailbox and the transaction ID.

Alice notifies Bob that the transaction on her side is complete, by passing in the transaction ID.

7. Bob receives this notification, and removes the transaction entry with the given transaction ID.

16.2. Fault Tolerance Behaviour

16.2.1. CellApp Fault Tolerance

If the CellApp that Alice's and/or Bob's cell entity resides on exits, all cell entities that have base entities will be restored to another CellApp. With this example scenario and transaction as described, there is not much of concern with regards to behaviour of restored cell entities as the transaction only involves BaseApps.

However, suppose the inventory system implementation was such that the player cell entities required knowledge of items, for example, what item a player was holding in its hands, which would need to be a `OTHER_CLIENTS` or `ALL_CLIENTS` cell entity property so that other players could view the item that a player was holding. If the cell entity was restored from an older version of its cell entity data when it was last backed up to the base entity, there could be inconsistencies in the cell entity state with respect to the base entity state.

For example, if Alice was restored to another CellApp, her cell entity could check with her base entity whether she still owned the item that she was holding, and if not, her cell entity should remove that item.

Cell entities that are restored do not have their `__init__`() method called, instead, after they are restored with the cell backup data from their base entity, they have their `onRestore`() method called, and checks such as these can be done in this method to make sure the state is consistent with the base entity state.

16.2.2. BaseApp Fault Tolerance

If the BaseApp that Alice's and/or Bob's base entity resides on exits, those base entities will be restored to other BaseApps if they exist (if there is only one BaseApp, they cannot be restored).

As with cell entities, restored base entities do not have `__init__`() called on them, instead, they have `onRestore`() called on them when they are each restored from their most recent base entity backup data. This is a good place to do checks on uncompleted transactions.

For example, if the BaseApp that contained Alice exited, and Alice was restored onto another BaseApp (and perhaps Bob was too, and it could be a different BaseApp to where he was), then we need to replay any transactions that may have been underway.

For each transaction entry in Alice's transaction list, the entity needs to replay each transaction depending on the state that it's in.

For example, if it is in the `BEGIN` state, we resume the transaction from step 3 by looking up Bob's base entity, and continuing on.

If we are Bob, we may have transactions in the `REMOVE` state, and so we resume the transaction from step 6, and we tell Alice (or whoever the transactions' player name refers to) that they should complete the transaction on their end.

16.3. Disaster Recovery Behaviour

When we are starting the server and restoring from the database, the base entities will be restored, and each of these will have `__init__`() called on them. The variable `BigWorld.hasStarted` will be `False` for restored base entities, so we can do similar checks to what we have in the BaseApp fault tolerance section.

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It is also the responsibility of the base entities to recreate the cell entities, usually via `createCellEntity`(). The space ID is archived with the entity when it is written to the database, and this is present in the base entity's `cellData` dictionary.

Chapter 17. User Authentication and Proxy Selection

In the document Server Overview's section *Design Introduction* → Use cases → Logging in, an overview of the login process is given. This chapter details that process, describing the tables and columns involved during the login process.

The DBMgr plays an important role in the login process, as it determines:

- Whether the username and password are valid.
- Which Proxy entity to load for the user.

It is highly recommended to use the MySQL database back-end when implementing user authentication. The XML database differs significantly from the MySQL database in this area. A solution that works with the XML database will most likely not work for the MySQL database, and vice-versa. The following sections assume that the MySQL database back-end is being used.

17.1. The bigworldLogOnMapping Table

DBMgr uses the `bigworldLogOnMapping` table (for details, see “Entity Tables” on page 159) to check login's validity and which Proxy to load for the user. It contains the following columns:

- **`logOnName`**

  Username used to log in BigWorld. This is the primary key.

- **`password`**

  User's password.

- **`typeID`**

  Type ID of the Proxy entity to create. To map the type ID to its name, `bigworldEntityTypes` table (for details, see “Entity Tables” on page 159 .) is used, which columns are described below:

  - **`type`**

    ID of entity type, matched with `bigworldLogOnMapping` table's typeID column to do entity mapping.

  - **`recordName`**

    Name of entity type as specified in `<res>/scripts/entities.xml`.

    For details on this file, see “The entities.xml File” on page 11 .

To determine whether a login is valid and which Proxy entity to load, DBMgr executes the following steps:

1. Find a row in the `bigworldLogOnMapping` table where the `logOnName` column matches the username.
2. Check that the user's password matches the password of the found row.
3. Load the Proxy entity identified by `typeID` and `recordName`.

For this step to succeed, the Proxy entity must already exist in the database. For information on how to create an entity and write it to the database, see “Reading and Writing Entities” on page 68 .

BigWorld currently does not provide an API for manipulating `bigworldLogOnMapping`, therefore it is usually populated using MySQL tools. For information on how BigWorld under some circumstances automatically populates this table, see “Accepting All Users” on page 115 .

17.1.1. The bigworldLogOnMapping Table in the XML Database

The XML database implements the equivalent of the `bigworldLogOnMapping` table in the section `_BigWorldInfo/LogOnMapping`. Each row is specified using a separate sub-section, as illustrated below:

```
<root>
  <_BigWorldInfo>
    <LogOnMapping>
      <item>
        <logOnName>  John      </logOnName>
        <password>   acde1234  </password>
        <type>       Account   </type>
        <entityName> Achilles  </entityName>
      </item>
      <item>
        <logOnName>  Peter     </logOnName>
        <password>   zyxw9876  </password>
        <type>       Avatar    </type>
        <entityName> Hercules  </entityName>
      </item>
    </LogOnMapping>
  </_BigWorldInfo>
...
</root>
```

bigworldLogOnMapping table in XML

In the example above, two rows are specified. The tags correspond to the table columns as described below:

- **`logOnName`** - Corresponds to column: `logOnName`
- **`password`** - Corresponds to column: `password`
- **`type`** - Corresponds to column: `typeID`
- **`entityName`** - Corresponds to column: `recordName`

When specifying the type of the entity, the type name is used instead of the type ID used by the MySQL database.

Please note that `<res>/scripts/db.xml` is only read and written to during startup and shutdown, respectively. Therefore, it is not possible to update the `_BigWorldInfo/LogOnMapping` section and have the changes take effect while DBMgr is running.

17.2. Accepting All Users

During development, it is often convenient to grant all users access to the server, without having to set up a `bigworldLogOnMapping` table.

This can be achieved by setting `bw.xml` file's `dbMgr/createUnknown`[1] configuration option to `true`. With this configuration, a default entity is created for the user if there is no row matching the username in `bigworldLogOnMapping`.

The type of the entity created is controlled by the `bw.xml` file's `dbMgr/entityType` option. Additionally, if `dbMgr/rememberUnknown` is set to `true`, then the entity created for the unknown user is saved in the database, and an entry is added in `bigworldLogOnMapping`. This effectively adds a new user into the system, and subsequent logins by the same user will be processed via the normal login process.

[1] For details, see the document Server Operations Guide's section *Server Configuration with `bw.xml`* → "DBMgr Configuration Options".

17.3. Bypassing bigworldLogOnMapping and Using Account Entity

The login processing implemented by the DBMgr is often insufficient for games that require interaction with an external billing system. For this reason, the source code is provided.

Alternatively, to avoid having to modify DBMgr code, user authentication, and Proxy selection can be delegated to an account entity. An account entity is just another BigWorld entity that is implemented using Python script. The DBMgr can be configured to bypass its usual login processing and pass control over to the account entity.

Firstly, the `bigworldLogOnMapping` table (for details, see "Entity Tables" on page 159) must be emptied.

Then, the following configuration options must be set:

- **`dbMgr/entityType`[A] - Required value: Your account entity type**

  Reason for required value:

  Type of the entity that will handle the login process.

  For details on how to implement entities, see *Physical Entity Structure for Scripting* on page 11 .

- **`dbMgr/loadUnknown`[A] - Required value: `true`**

  Reason for required value:

  Since at this stage `bigworldLogOnMapping` table will be empty, all logins will be considered '*unknown*'.

  When this option is set to `true`, DBMgr tries to find an existing entity of the type specified in `dbMgr/entityType` with a name that matches the username, and uses that as the Proxy entity. If no entity is found, then the login fails.

  Note

  The name of an entity is a property tagged with the `<Identifier>` tag. For details, see "The Identifier Tag" on page 67 .

- **`dbMgr/rememberUnknown`[A] - Required value: `false`**

  Reason for required value:

  To preserve the emptiness of `bigworldLogOnMapping`.

A *- For details, see the document Server Operations Guide's section Software Configuration with `bw.xml` → DBMgr configuration options.*

With the above configuration, whenever a user logs in, an account Proxy entity with a name matching the username will be loaded. If there is no account entity matching the username then the login will fail.

After a successful login:

- **On the client** - The account's `__init__` method is called.
- **On the BaseApp** - The account's `onEntitiesEnabled` method is called.

There are a couple of approaches to retrieving the user's password:

- On the BaseApp, if the account entity has a property called password, it is automatically set to the user's login password. And, of course, the account's name property will try to match the username.

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- Since the login password sent by the client using BigWorld.connect method is usually sent in clear text, it may be preferable to use an empty password for normal login processing. Then, after the account entity has been created, the client can send an encrypted password to the Proxy.

It is up to the account entity's implementation to verify the user's password. This is usually done by communicating with a third-party billing system. For details on how to communicate with a non-BigWorld process, see *Non-Blocking Socket I/O Using Mercury*on page 158. If the user's password is invalid, then the Proxy entity can destroy itself to disconnect the client.

If the `<dbMgr/createUnknown>` [2] configuration option is set to `true`, then a default account entity will be created for any unknown user that logs in. This can be useful - even on production servers - to implement a recruitment feature. The account's Proxy entity can write itself into the database by calling its `writeToDB` method, effectively adding a new user to the game. Alternatively, the Proxy entity can destroy itself without writing to the database, effectively forgetting that the login ever took place. However, this configuration will leave the server more susceptible to denial-of-service attacks since anyone can cause account entities to be created on the server.

17.4. Using bigworldLogOnMapping Table with an Account Entity

One of the advantages of using the `bigworldLogOnMapping` table for processing login is to be able to reject invalid logins early in the process. When using an account entity, the user's password is not verified until after the account entity has been created. This makes the server more susceptible to denial-of-service attacks.

By setting `<dbMgr/loadUnknown>` to `false`, and updating the `typeID` and `recordName` columns of the `bigworldLogOnMapping` table to refer to an account entity, both methods can be combined. The `password` column can also be set to something other than the user's password. For example, a CD key can be used. Then an account entity will only be created if the user has a valid CD key. Once the account entity is created, the user's password can be verified.

[2] For details, see the document Server Operations Guide's section *Server Configuration with* `bw.xml` → "DBMgr Configuration Options".

Chapter 18. Security

Any MMOG needs to implement robust solutions to safeguard its environment from exploits. This chapter describes the measures adopted by BigWorld to provide safety for your data.

18.1. Client/Server Communications

The list below describes the measures taken to guarantee the security of client/server communications:

- **Security measure: Login authentication**

  Opportunity thwarted: Unknown user using a player's account.

  When a player logs in to a BigWorld server, he sends a username and a password. These are compared to a server-side database, to make sure that the user is subscribed.

  The source code is available to the login procedure, so this method can be customised as desired.

- **Security measure: Packet authentication**

  Opportunity thwarted: Player pretending to be someone else, by spoofing another player's data.

  When a player logs in to a BigWorld server, the server sends a 32-bit session key back to the client. The client must use this key in all further packets sent to the server, or the packet will be rejected.

  Optionally, the server can also send to the client an authentication key with every packet. This makes it very hard for an attacker to successfully masquerade as the server.

  Also, every command called on the server has the client's ID added to the arguments. This is done by the BaseApp before the command is transmitted, so the client cannot fake the ID.

- **Security measure: Encryption**

  Opportunity thwarted: Attacker sniffing data to gain privileged information, or injecting new packets into client-server streams.

  All traffic between the client and server is encrypted. The credentials sent to the server during login are RSA-encrypted and all client-server traffic after this point is encrypted with 128-bit modal Blowfish. This makes it very difficult for an attacker to inject new packets into either the upstream or downstream traffic; without knowing the Blowfish key, the probability of generating a packet that will parse correctly and not be discarded is extremely low.

  It would still be possible for a player to hack its own binary and sniff the data stream from the server after it has been decrypted.

- **Security measure: Data hiding**

  Opportunity thwarted: Player accessing privileged information.

  All properties of entities are tagged with propagation specifiers. These allow the server to control where information is sent.

  For example, you may want to hide the actual health of NPC players, to prevent players from cheating by sniffing the data stream.

  This is a common problem on MMOGs that receive data that is not always displayed to the user.

  For more details, see “Data Distribution” on page 26 .

- **Security measure: Sequence numbers**

Opportunity thwarted: User spoofing and replaying captured stream.

All packets are stamped with a sequence number, and packets are rejected if the number is duped.

This makes it much harder for a hacker to capture a data stream and replay it, or inject packets to fake game operations.

- **Security measure: IP address masking**

  Opportunity thwarted: User doing DOS attacks on clients.

  A player's IP address is not shared between clients, making it impossible for hackers to sniff it and then perform a Denial Of Service attack on that client.

- **Security measure: Privilege checks on RPCs**

  Opportunity thwarted: Player calling server-only functions.

  Both client and server entities call functions (Remote Procedure Calls) on Python objects.

  The developer tags all methods with accessibility flags. This enables the server to check all calls to make sure that they are legal.

18.2. Server-Side Network

Security for the internal server-side network is provided by a simple proxy mechanism - the only machines exposed to the Internet are the LoginApps and BaseApps (for more details, see the document Server Overview's section Server Components → BaseApp).

As such, internal server traffic between BigWorld components (*e.g.*, CellApp to BaseApp traffic, CellApp to CellAppMgr traffic) cannot be sniffed.

Additionally, each server component is only required to listen for all external communications on a single UDP port. This way, all other network services can be disabled, including TCP, which is the target of many known attacks. Listening on a single UDP port for communications with all clients (as opposed to a distinct port for each) also has the following advantages:

- It becomes impossible for one client to guess another's port, and thereby impersonate it.
- A single `recv()` is used for all incoming messages on the server side, instead of a `select()` across a large number of per-player sockets. This results in a more efficient message handling implementation.

18.3. Client Side

The list below describes the measures taken to guarantee the security of the client side:

- **Security measure: CD Key**

  Opportunity thwarted: Stealing of CD images

  BigWorld Technology does not cover distribution issues.

  But since an MMOG client must connect to a server to play the game, this problem can be solved by modifying the login process so that, in addition to the username and password, the CD key is also sent to the server and checked against a database.

18.4. Client Cheating

As a developer, you need to watch out for hacked clients, and third party apps (often called 'trainers'). It is also important to realise that it is very hard to prevent all forms of cheating. You should decide what forms

of cheating will impact you and/or your customers, and work on those issues, and do not let minor cheating distract you.

The most important rule is to always be careful with data sent from the client. If possible, everything that the client does should be checked for validity on the server. Simple rules, like ensuring that a switch can only be activated when the player is close enough to throw the lever, are easy to enforce. To simplify these checks, an extra 'source' argument is added to the parameter list for every method exposed to the client. The client does not send it up - it is added by the BaseApp automatically. Also, to make it harder for clients to cheat, methods not exposed to the client are excised from the address space that it sees.

Generalised physics checking on more frequent interactions, such as movement, is not so easy, since running the physics of every player on the server would be quite expensive. One solution is to use the high-level geometry of the world as the expression of the important physical rules. The world is built up of polyhedral chunks connected by portals. A chunk equates to one room in inside areas. Whenever the player moves between chunks, we check that the movement passes through a portal, and that the player has not moved too fast. This means that we are not concerned about petty violations of physical rules, like standing in the middle of a table, but we do catch violations that influence the game, like moving through walls or locked doors, and moving too quickly.

18.4.1. General Rules for Managing Entity Data

The general rule is to send data to the client only if it is necessary. This saves bandwidth, as well as helping reduce hacking. There are three techniques you can use with BigWorld Technology:

- **Level of Detail**

  Instead of constantly sending entity information, you might want to send it only when it is within range. For example, a player might be able to see a monster from 500 metres away, but its level does not have to be sent to the client until it is within 20 metres.

- **Data hiding**

  Some information should never be sent to the client. For example, NPC health could be kept local to the server, and the client can just call functions that affect it (*e.g.*, `doDamage(10)`). The server sends the results to the client (*e.g.*, monster limping because health is below 50%).

- **Data on request**

  The client should call server functions to request data only when needed. For example, your game could be designed such that the client must physically 'con' a monster by calling a server-side function that returns level and health. To detect potential cheating the server could then flag clients that con more than one monster per second, or con monsters further than 20 metres away.

18.4.2. Writing Secure Game Script

As mentioned in other places, the responsibility for security in a BigWorld-based game is shared between the engine itself and the game script running on top of it. In particular, script writers must be very careful in the design and implementation of `<Exposed/>` methods. Please see “Exposed Methods - Client-to-Server Communication” on page 43 for more details on the specifics of the security requirements for exposed methods.

Note

Please be aware that at this point in time, the FantasyDemo game that ships with each BigWorld package has not been bulletproofed against the actions of malicious clients and in all likelihood contains security vulnerabilities in its exposed methods. We are working on improving this and offering a FantasyDemo to customers that serves as both a good feature demonstration as well as a good example of secure script.

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18.4.3. Balancing Security vs. Latency

As much as security is important, as a developer you have to be careful so that it does not impact too much the player's experience of the game.

The game has to be responsive, but the game play may feel very lagged if the client passed all movement and combat commands to the server for validation before showing results. Therefore, you are best off handling movement on the client side, or simultaneously on the client and the server. For example, to have a fast-paced shooting game, you would need to perform client-side tests for impact, and show the result immediately (monster recoils when hit, etc...). Simultaneously, you would send the shoot command to the server, and let the server send down any changes of health if the monster is really hit. This means that the client cannot cheat with shooting, but still gets lag-free results.

18.4.4. Balancing Security vs. Server CPU Cost

This is one of the biggest issues in controlling hacking. For example, it may be too expensive to check all player physics on the server. The developer has to pick the most common forms of cheating, and check for those.

It is sensible to allow checks to be turned on and off per player, or only check 10% of the players at any one time. Statistical checking can be useful, for example by monitoring how many XP are gained over time by players, to check if they are accumulating points at an unfeasible rate. If the player becomes a suspect of cheating, then more checks can be turned on for him.

Chapter 19. Debugging

19.1. General Debugging

19.1.1. Information and Error Messages

When running the server using BWPanel, script messages and errors are displayed in the console of the corresponding application (*i.e.*, the output of a base script is displayed on the BaseApp console, and the output of a cell script is displayed on the CellApp console). Similarly, the output of message macro statements in C++ will be displayed in the corresponding application console.

When running the server using `control_cluster.py`, for example, there may not be a console associated with an application. In order to view process messages when not running from the console the server tools MessageLogger[1], and WebConsole[2] should be used for collecting process output and viewing log messages respectively.

19.1.2. Testing Scripts Using the Python Server

In order to test Python scripts and behaviour on a live server a telnet server can be connected to on both the BaseApp and CellApp processes to run script. The telnet server by default is run on port 40001 for a BaseApp, and 50001 for a CellApp, but both can be configured in the file `<res>/server/bw.xml` using the `<pythonPort>` configuration option.

If the desired port is already used on the application's machine, then a random port is chosen. You can find out the assigned port by looking at the log output of the particular BaseApp or CellApp for a line such as the following:

```
INFO: Python server is running on port 33225
```

This value can also be found in the watcher value `pythonServerPort`.

Note

This is intended primarily as a development time only utility and should be used sparingly in a production environment. Performing CPU intensive Python operations such as listing all entities may adversely affect game behaviour for your clients.

Telnet can be used to connect to the Python server of each BaseApp and CellApp, which provides a Python console that can be used for

There are currently three methods of connecting to the Python telnet server.

1. Connecting via WebConsole
2. Connecting via `control_cluster.py`
3. Connecting via the commandline using telnet

Connecting to the Python server via WebConsole is the recommended method of interacting with the Python server as it allows access to the other server debugging tools as required. To connect through WebConsole simply select the *Python Console* module from the menu on the left hand side of the main WebConsole page.

[1] For details on MessageLogger, see the document Server Operations Guide's section *Admin Tools* → "Logger Daemons" → "MessageLogger".

[2] For details on WebConsole, see the document Server Operations Guide's section *Admin Tools* → "WebConsole".

To connect using `control_cluster.py`, simply use the `pyconsole`[3] option. For example, to connect to the second CellApp in a cluster:

```
$ ./control_cluster.py pyconsole cellapp02
```

To connect using telnet, after determining the port the process has an active python server on simply provide telnet with the *hostname* and *port*. For example, to connect to a machine called `cluster01` running a BaseApp with a Python server running on port `40001` the following command would be used:

```
$ telnet cluster01 40001
```

Once connected to the Python console server it is possible to call script methods. For example, in FantasyDemo, the player entity is called `Avatar`, and it is possible to access its cell or base parts after a player logs in:

```
$ telnet cluster02 50001
Trying 10.40.3.4...
Connected to cluster02.
Escape character is '^]'.
Welcome to Cell App 1
Build: 13:34:56 Apr 12 2005
> BigWorld.entities.keys()
[4848, 4849]
> BigWorld.entities[4848]
Avatar at 0x08533FDC
> avatar = _
> avatar.playerName
'Trogdor the Burninator'
> avatar.beginTrade()
```

Accessing an avatar via the Python console on the cell

19.2. Performance Profiling

Python has helpful modules that can be used to profile your script. BigWorld exposes the method **_hotshot** through the watcher interface, to help with profiling BigWorld script.

To start profiling, set the watcher `pythonProfile/running` to `true`. The profiler outputs its log to a file with the filename specified by the watcher `pythonProfile/filename`, the file name being relative to the current working directory, most likely to be `bigworld/bin/Hybrid`. Setting the watcher `pythonProfile/running` to `false` ends the profiling session, and closes the profile log.

To inspect the log, use the module **hotshot.stats**.

For example,

```
$ python
> import hotshot.stats
> stats = hotshot.stats.load( "cell.prof" )
> stats.sort_stats( "time", "calls" )
> stats.print_stats( 20 )
```

[3] For more information regarding this option see the `control_cluster.py` program help using the `--help` flag.

Please note that there may be problems inspecting the profiling log, if the call stack depth gets smaller than when the session was started, or the session is stopped at a different call stack depth. Due to that, care must be taken when starting and stopping profiling from script.

It is also possible to use the module **_hotshot** in script. This may be helpful if you only want to profile specific parts of the script. A profiler object can be created, and then started and stopped over a specific method call.

For example, the following could be added to file `fantasydemo/res/scripts/cell/Creature.py` to profile the method `Creature.onTime`:

```
import _hotshot
profiler = None

def startProfiling():
  global profiler
  profiler = _hotshot.profiler( "creature.prof" )

def stopProfiling():
  global profiler
  profiler.close()
  profiler = None

class Creature( BigWorld.Entity ):
  def onTimer( self, timerId, userId ):
    if profiler:
        profiler.start()

    # Normal function body

    if profiler:
        profiler.stop()
```

This can be started and stopped with something like the following.

```
$ telnet bgserver 50001
Trying 10.40.3.4...
Connected to bgserver.
Escape character is '^]'.
Welcome to Cell App 1
Build: 13:34:56 Apr 12 2005
> import Creature
> Creature.startProfiling()
> Creature.stopProfiling()
```

For more details on the hotshot module, see the Python documentation at http://docs.python.org/lib/module-hotshot.html.

19.3. Common Mistakes

19.3.1. Definition Files Inconsistent Between the Server and Client

To ensure that the client can understand the data sent by the server, the definition files must be kept consistent between them.

A client will not be able to log in if it has inconsistent definition files. The LoginApp and the DBMgr produce the following error:

```
INFO: LoginApp::sendFailure: LogOn for 10.40.3.17:2254 failed 'Bad digest'
```


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19.3.2. Implementation (.py) Does Not Match Definition (.def)

For each entity type, its Python script must implement the methods described in its `.def` file. The server will report an error if this does not occur.

For example:

```
ERROR: EntityDescription::checkMethods: class Avatar does not have method
 sendMessageToFriends
ERROR: EntityType::Type: Script for Avatar is missing a method.
```

19.3.3. Accessing Other Entities' Properties and Methods Not Declared in the Definition File

It is possible to access a property of another entity when it is on the same process as the calling entity. This is true for both base and cell entities.

This works during initial testing, when only one BaseApp and one CellApp are used, but is likely to not work when more BaseApps and CellApps are used.

Properties of remote entities cannot be written to directly (i.e. they are read-only), regardless of whether those properties are declared in the `.def` file. Also, only methods declared in the `.def` file can be called when the entity is on another application.

19.3.4. Trying to Update the Properties of a Ghost Entity

Sometimes the game design might have two entities moving through the world close to each other, as would be the case of an Avatar and a Bodyguard, or a Pet. Due to their proximity, developers might assume that they will always be located in the same cell as each other, and thus have one of the entities try to update a property on the other (*e.g.*, `self.bodyguard.armour=true`, or `self.pet.state=Alert`).

Though this will not cause problems most of the time, it might happen that the two entities are separated by a cell boundary, and thus will only have access to the other one's ghost, which will cause the properties to be read-only.

To test for the existence of this kind of problem, CellApp has the configuration option `treatAllOtherEntitiesAsGhosts`. This option causes the CellApp to treat only its own entity as real, and all others as ghosts. For more details, see “Data Distribution” on page 26 .

This debugging mode allows script writers to catch these errors immediately instead of leaving them lurking in the background to only appear on rare occasions.

19.3.5. Database backup and fault tolerance doesn't work for entities lacking a Base part

As noted in the Python API documentation, the writeToDB() method can only be called on entities that have a Base part. That means you cannot persist entities that do not have a Base part.

The server's first-level fault tolerance (which restores entities when a CellApp dies) also relies on those entities having a Base part. The state of the entity is backed up from the Cell to the Base part over time and if the CellApp that is hosting an entity's Cell part disappears, the Base entity will restore it to another CellApp. This does not work unless you create each entity type with a Base and Cell part.

This means that you may need to declare more-or-less empty Base entity definitions for entities that don't have any Base methods, just so that they can be written to the database and so that they will be restored in the event of a CellApp crash.

19.4. Fixed Cell Boundaries

To help the testing and debugging of the transitioning of entities between CellApps, it can be helpful to have fixed cell boundaries.

Typical things that could be tested this way include:

- Controllers and entity extras implemented in extensions.
- Script interaction of entities on different CellApps.
- Streaming of entity properties.

To configure fixed cell boundaries in BigWorld, follow the steps below:

- Start the server including at least two CellApps.
- Make sure that cells are created on all CellApps by setting the configuration options `cellAppMgr/cellAppLoadLowerBound` and `cellAppMgr/cellAppLoadUpperBound` to `0.0` in file `<res>/server/bw.xml`. These options can also be changed with the watcher values `cellAppLoad/balanceLowerBound` and `cellAppLoad/balanceUpperBound` of CellAppMgr.
- Disable load balancing by setting the CellAppMgr watcher value `shouldLoadBalance` to `false`.
- It can also be convenient to set the exact position of a partition. Currently, only the root partition of a space can have its position set. This can be set with the CellAppMgr watcher value `space/<spaceID>/rootPartition`, where `<spaceID>` is the space ID.

19.5. Message Reliability And Ordering

BigWorld is a networked, distributed system, and as such, script writers need to be aware of the reliability and ordering issues that can arise in such a system. All non-volatile messages are reliably delivered. BigWorld guarantees not only the reliable delivery but also the in-order delivery of some messages. These are:

- Messages sent between Proxy and Client
- Messages sent between the Base and Cell part of the same entity
- Messages sent between two Base entities
- Messages sent between any pair of server processes
- Updates sent from a real entity to its ghosts

The offloading of Cell entities from one CellApp to another can cause some messages to be delivered slightly out-of-order. This means your game script may need to cope with method calls and property updates being slightly out-of-order if they are triggered by any of the following message types:

- Messages sent between two different Cell entities
- Messages sent between the Cell part of one entity and the Base part of another
- Messages sent between the Cell part of one entity and the Client part of another

It is important to note that the probability of out-of-order delivery of these messages is directly proportional to the amount of packet loss on the network the server processes are running, *i.e.* this re-ordering cannot happen unless you are getting some degree of packet loss. We cannot emphasise enough the importance of using good quality hardware (both computers and network hardware) in your production deployment clusters, and having enough hardware in your clusters that you can run your game servers with an ample

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amount of CPU and network capacity to spare. BigWorld's experience with customer deployments has shown that inferior and/or insufficient hardware is likely to cause critical (*i.e* showstopping) problems at runtime.

Chapter 20. Simplified Server Usage

For anyone not familiar with both Windows and Linux, running a BigWorld server on a Linux box to test game scripts and/or assets can be intimidating and error prone. Additionally, since designers and artists typically do most of their work on Windows, the process of synchronising files between the Windows and Linux machines can be tedious.

The solution presented here aims to simplify this task by having all assets and game scripts reside on the Windows machine, with a Linux box (which can be shared among multiple users) hosting and running the BigWorld server binaries.

Basically, the solution proposes the following:

1. User exports the root BigWorld directory (*i.e.*, the directory containing `bigworld`, `fantasydemo`, and `src` folders) as a Windows share.

2. Linux box mounts the relevant `<res>` directories inside the `bigworld` folder on the Linux filesystem.

This makes game development easy for a Windows-based developer/artist, since all editable files reside on the machine they are working on.

Note

The solution intentionally keeps the server binaries on the Linux box.
Running server executables pulled from SAMBA-mounted filesystems causes unexpected problems, and is not recommended.
Running server binaries from NFS-mounted filesystems, however, works correctly.

20.1. Setting up the windows share

To share the `mf` directory on the Windows machine, follow the steps below:

1. Select the `mf` directory and right-click it.

2. In the context menu, select the **Sharing and Security...** menu item.

3. On the **mf Properties** dialog box, select the **Share This Folder** option button.

4. In the **Share Name** field, type the name to share the folder by (in our example, **mf-win**).

5. Click the **Permissions** button.

6. In the **Permission For mf** dialog box's **Group or User Names** list box, select the **Everyone** item.

7. In the **Permissions For Everyone** list box's **Full Control** entry, select the **Allow** check box.

20.2. Mounting the Windows share on Linux

To assist the process of mounting the Windows share, BigWorld provides the script `bigworld/tools/server/install/setup_win_dev.py`.

Please note, however, that it was designed for developers working at BigWorld, and hence it uses default values appropriate for BigWorld as well. Before artists and game programmers use it, a sysadmin or programmer should edit this file to change the defaults to values appropriate for your development environment.

This script works on the following assumptions:

- You are using CVS - if you wish to use this script in a Subversion-based environment, then a search-and-replace should be done.
- The server binaries are stored in the CVS repository.
- Your username on the Windows box is the same as your username on the Linux box.
- You are using Fedora Core 5 or later (this script has not been tested on Debian).

The script displays a list of prerequisites upon startup, which are reproduced here for convenience:

- You have been entered in the `sudoers` file (for details, issue the **man sudoers** command) on the Linux box.
- You know the appropriate `$CVSROOT` for your environment.
- You know where your home directory will be on the Linux box.
- You have shared the root BigWorld directory on your Windows box.

Once these requirements have been met and/or the necessary modifications have been made for your environment, running `setup_win_dev.py` will perform the following actions:

- Create your home directory on the Linux machine if it does not already exist.
- Mount your Windows share using Samba and patch `/etc/fstab` (so it can be easily mounted in the future).
- Detect the `<res>` folder in your Windows share and ask you which ones should be symlinked into the Linux BigWorld folder.
- Request the order in which the `<res>` folder should appear in your `$BW_RES_PATH`.
- Set up your `~/.bwmachined.conf` file.
- Fetch the server binaries from CVS.

Once the actions above have been performed, you can use WebConsole from your Windows box to:

- Start and stop a server.
- View server output.
- Connect to the Python Console of a running server process.
- Perform other administrative functions.

20.3. Caveats

At present, `setup_win_dev.py` does not insert your Windows password into the `/etc/fstab` entry. This is because the file is world-readable by default, which would expose the passwords.

The downside to this approach is that the Linux box will not be able to automatically remount any Windows shares at boot time - the shares have to be manually mounted via the shell, and each user's password must be entered. If the Linux box is rebooted often, then this can be time consuming.

If you consider your internal security robust enough to have your Windows passwords in `/etc/fstab`, then you can add the passwords in the options section of the relevant mounts in `/etc/fstab`.

Part II. Server C++ Programming Guide

Table of Contents

Chapter 21. Overview

This part of the document contains technical information for extending and customising the BigWorld Server. It is part of a larger set of documentation describing the whole BigWorld system.

The intended audience is technical-MMOG developers with game-specific needs that require the efficiency of C++ extensions.

For API-level information, please refer to the API reference documentation.

Chapter 22. Extending BigWorld Server

The best way of extending BigWorld is to take advantage of its extension loading mechanism. When a CellApp or BaseApp component of the system is loaded, it checks for executable objects in its extensions directory, and dynamically loads each one separately, in alphabetical order.

The extensions directory is located in the same folder of the component executable, and is named after it, with the `-extensions` suffix.

For example, the CellApp's extensions directory is cellapp-extensions, and is normally located under folder `bigworld/bin/$MF_CONFIG`.

The BigWorld server file `bigworld/src/server/common/common.mak` contains many definitions to ease the compilation of server extensions, and it is recommended that you use of it.

The format of a Makefile for an extension is described below (italics indicate placeholders):

```
SO = extension_name
COMPONENT = component_name
SRCS = source files

include $(MF_ROOT)/bigworld/src/server/common/common.mak

all::
```

The list below describes the Makefile entries:

- **`SO`**

  Name chosen for the extension.

- **`COMPONENT`**

  Name of the BigWorld component to extend (CellApp or BaseApp).

- **`SRCS`**

  List of sources files to compile, separated by white spaces (excluding the suffix '`.cpp`').

There is no blueprint for what an extension must do, and there is no API that is called by the host component. In general, any functionality that does not damage the operation of the host component may be compiled into an extension, including launching threads, and sending network messages. However, extensions must take great care not to block the main thread of the component while running in the game.

Since an extension is a dynamic library, it does not have any standard entry point such as `main`(). Usually, an extension must have static initialisers that call back into its host component to hook in somewhere, or else the extension will have no way of being executed. Most BigWorld systems have macros that create such static initialisers automatically, such as `IMPLEMENT_CHUNK_ITEM` for a chunk item type.

The BigWorld infrastructure is modular, and there are many ways to hook into it without changing the underlying code (which is fixed in the component binary).

Some examples of places to hook in are:

- New chunk item types.
- New ResMgr file systems.
- Entity extras.

- Controllers.
- Loading thread jobs.
- Network packet filters.
- Game tick (and higher resolution) timer queues.
- New Python functions or object types.
- New basic entity data types.

These are all ideal candidates for compiling into extensions.

The following sections describe some of the most useful and sophisticated extensions.

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Chapter 23. Entity Extras and Controllers

BigWorld provides two mechanisms for extending Entity and server functionality. These are known as *Entity Extras* and *Controllers*.

Entity extras provide a mechanism for adding additional methods to all BigWorld cell entities. They are created on the spot when accessed by an entity, and are otherwise stateless. They are lost when the entity changes cells. There is at most one instance of EntityExtra per entity, and it may be easily retrieved from an Entity reference.

Controllers provide a standard method to perform CPU-intensive work on entities in C++. They are instantiated by, and attached to a cell entity, and travel with it between cells. They are useful for performing actions that are either unfeasible or inefficient to implement in Python. There may be multiple Controller instances per entity, each with its own ID, which the entity script (or another Controller) may use to cancel or access the entity.

Thus, it is not possible to retrieve a Controller instance by type from an entity reference, since it would not be possible to determine the instance retrieved. Of course, a friendly EntityExtra could store a pointer to it, if this were desired.

BigWorld comes packaged with a selection of proven useful entity extras and Controllers, including facilities for performing the following functions:

- Movement and navigation.
- Vehicle management.
- Entity vision and visibility.
- Timed events.

Depending on game design, however, additional facilities may be needed. Game design may also dictate the need for different implementations of one or more of the supplied facilities. Custom entity extras and Controllers are often useful for implementing these game-specific features.

23.1. Implementing Entity Extras

Entity extras attach additional methods to the `BigWorld.Entity` Python class on the cell. All entities have access to all methods of entity extras. However, the class implementing an entity extra is not instantiated until one of those methods is used, thus saving memory.

While entity extras are useful for extending entities in ways that can only be done via C++, it is worth remembering that for many things a simple Python base class will suffice.

Entity extras should not contain any state for an entity, as they are not streamed from one cell to another during the cell's ghosting process.

A minimal entity extra consists of the following header file (replacing any references to `EgExtra` with the appropriate name):

```
#ifndef EGEXTRA_HPP
#define EGEXTRA_HPP

#include "../cellapp/entity_extra.hpp"

/**
 * Simple example entity extra... can print a message to the screen
 */
```

```
#undef PY_METHOD_ATTRIBUTE_WITH_DOC
#define PY_METHOD_ATTRIBUTE_WITH_DOC PY_METHOD_ATTRIBUTE_ENTITY_EXTRA_WITH_DOC

class EgExtra : public EntityExtra
{
  Py_EntityExtraHeader( EgExtra );

public:
  EgExtra( Entity& e );
  ~EgExtra();

  PyObject * pyGetAttribute( const char * attr );
  int pySetAttribute( const char * attr, PyObject * value );

  static const Instance<EgExtra> instance;
};

#undef PY_METHOD_ATTRIBUTE_WITH_DOC
#define PY_METHOD_ATTRIBUTE_WITH_DOC PY_METHOD_ATTRIBUTE_BASE_WITH_DOC

#endif
```

EgExtra header file `bigworld/src/server/egextra/egextra.hpp` - Minimal definition

The code above contains the declarations necessary to integrate an entity extra into any entity in the BigWorld system.

After the header guards, `bigworld/src/server/cellapp/entity_extra.hpp` is included which defines the `EntityExtra` class.

It also overrides the macro `PY_METHOD_ATTRIBUTE`, in order to make automatically declared Python attributes in `EntityExtra`s work[1]. This allows BigWorld to search through and automatically instantiate extras by using only the name of the method that has been called.

In the `EgExtra` class, we derive from `EntityExtra`, and use the macro `Py_EntityExtraHeader` to declare some additional methods and properties that are used to keep track of these classes.

We provide the methods `pyGetAttribute` and `pySetAttribute` so that we can act like a Python object.

A static specialisation `EntityExtra::instance` member is also declared to access the entity extras. With it, we can get a reference to the `EgExtra` for any `Entity& ent` using the code:

```
EgExtra& eg = EgExtra instance( ent );
```

If the extra does not exist, it will be instantiated and returned. If we wanted to check first whether the extra exists, we can query it with the following code:

```
bool hasEgExtra = EgExtra instance.exists( ent );
```

We implement the outline of the `EgExtra` class as follows:

```
#include "egextra.hpp"

DECLARE_DEBUG_COMPONENT(0);
```

[1] Note that this is undone at the end of the file.

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```
PY_TYPEOBJECT( EgExtra )

PY_BEGIN_METHODS( EgExtra )
PY_END_METHODS()

PY_BEGIN_ATTRIBUTES( EgExtra )
PY_END_ATTRIBUTES()

const EgExtra::Instance<EgExtra>
  EgExtra::instance( &EgExtra::s_attributes_.di_ );

EgExtra::EgExtra( Entity& e ) : EntityExtra( e )
{
}

EgExtra::~EgExtra()
{
}

PyObject * EgExtra::pyGetAttribute( const char * attr )
{
  PY_GETATTR_STD();
  return this->EntityExtra::pyGetAttribute( attr );
}

int EgExtra::pySetAttribute( const char * attr, PyObject * value )
{
  PY_SETATTR_STD();
  return this->EntityExtra::pySetAttribute( attr, value );
}
```

EgExtra implementation file `bigworld/src/server/egextra/egextra.cpp` - Class outline

These two files together constitute the framework that we will use to implement any entity extra. These files can be found in BigWorld distribution, in folder `server/egextra`.

We can now add methods to this entity extra. We do this by declaring the method in the class declaration, and exposing it to Python with the BigWorld Python macros.

As a simple example, to implement a method that prints the message '`hello world`' to the server debug log, we add the following code to the class declaration:

```
// ...

class EgExtra : public EntityExtra
{
  Py_EntityExtraHeader( EgExtra );

public:
  // ...

  void helloWorld();
  PY_AUTO_METHOD_DECLARE( RETVOID, helloWorld, END );
};

// ...
```

`EgExtra` header file - Declaration of method `helloWorld`

And in the implementation file, we add a simple 'stub' implementation:

```
// ...

PY_TYPE_OBJECT( EgExtra )

PY_BEGIN_METHODS( EgExtra )
  PY_METHOD( helloWorld )
PY_END_METHODS()

// ...

void EgExtra::helloWorld()
{
  DEBUG_MSG( "egextra: hello world\n" );
}
```

EgExtra implementation file - Definition of method helloWorld

After compiling this module, then for any entity in the world you can call:

```
self.helloWorld()
```

The call above outputs the text '`egextra: hello world`' to the server debug log.

Entity extras have an `entity`() function, which returns a reference to the entity they have been attached to.

23.2. Implementing Controllers

Controllers enable us to dynamically add stateful C++ objects to entities on the CellApp. They can be used for property updates that need to be continuous, or for extensions that need to interact with the server at a level lower than the one exposed via the scripted entity model.

To implement a Controller, inherit from the CellApp class named `Controller`. The Controller declaration has to include the special macro `DECLARE_CONTROLLER_TYPE`, which includes definitions required to register the Controller in the BigWorld system.

The stub declaration file contains the following code:

```
#ifndef EGCONTROLLER_HPP
#define EGCONTROLLER_HPP

#include "../cellapp/controller.hpp"

class EgController : public Controller
{
  DECLARE_CONTROLLER_TYPE( EgController );

public:
};

#endif
```

Controller header file - bigworld/src/server/egextra/egcontroller.hpp

A Controller may be a member of the real domain (denoted by `DOMAIN_REAL`), or the ghost domain (denoted by `DOMAIN_GHOST`).

- **A Controller member of `DOMAIN_REAL` works with reals.**

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An example would be a movement Controller. Positional data is already sent via the entity (due to the necessity of placing the ghost in the right position), but other clients are unlikely to need to know the entity's final destination. Consequently, there is no need to send ghost information for this entity. Therefore, the Controller needs to operate only in the real domain.

- **A Controller member of `DOMAIN_GHOST` works with ghosts.**

  One such controller is BigWorld's `VisibilityController`, which simply publishes information for other entities to query. Other entities need to query this Controller (through an entity extra) to determine whether they can see that entity, even when the entity is a ghost.

BigWorld directs Controllers by calling various virtual methods on the `Controller` class. There are two types of such methods:

1. **Communication methods**

   These methods serialise data onto a stream between cells, so that the Controller representation can be moved from one machine to another.

   There are four of these, one each for reading/writing to the real/ghost domains, as described below:

   - **Method: `Read`**
     - **`DOMAIN_REAL`: `bool readRealFromStream( BinaryIStream& )`**

       Returns `TRUE` on success. Default implementation: `return TRUE`.

     - **`DOMAIN_GHOST`: `bool readGhostFromStream( BinaryIStream& )`**

       Returns `TRUE` on success. Default implementation: `return TRUE`.

   - **Method: `Write`**
     - **`DOMAIN_REAL`: `void writeRealToStream( BinaryOStream& )`**

       Default implementation: Do nothing

     - **`DOMAIN_GHOST`: `bool void writeGhostToStream( BinaryOStream& )`**

       Default implementation: Do nothing.

2. **Start/stop methods**

   Controllers often request to be called back from the BigWorld code. However, a real Controller should not be executed when it is attached to a ghost entity, and a ghost Controller should not be executed when it is attached to a real entity.

   To allow this, BigWorld uses four Controller methods to notify a controller when it should change its processing strategy - start methods should request the callbacks, and stop methods should cancel them, as described below:

   - **Method: Start**
     - **`DOMAIN_REAL`: `void startReal( bool isInitialStart )`**

       Default implementation: Do nothing.

     - **`DOMAIN_GHOST`: `void startGhost( )`**

       Default implementation: Do nothing.

- **Method: Stop**
  - **`DOMAIN_REAL`: `void stopReal( bool isFinalStop )`**

    Default implementation: Do nothing.
  - **`DOMAIN_GHOST`: `void stopGhost( )`**

    Default implementation: Do nothing.

A Controller can be a member of both domains (`DOMAIN_REAL`, and `DOMAIN_GHOST`) if it has the (uncommon) need to present aspects of itself as a ghost Controller, and aspects of itself as a real Controller.

Once an initial decision has been made as to which domains a controller belongs to, a stub implementation file needs to be set up. At first, it does not have to declare the domain, as illustrated below:

```
#include "egcontroller.hpp"
#include "../cellapp/cellapp.hpp"

DECLARE_DEBUG_COMPONENT(0);

// controller type declaration needs to go here
```

Controller stub implementation file - `bigworld/src/server/egextra/egcontroller.cpp`

Next, a macro needs to be placed to implement the controller integration. There are two possible macros for that:

1. **IMPLEMENT_CONTROLLER_TYPE(CLASS_NAME, DOMAIN)**

   This macro declares a standard Controller type, which will be instantiated using an `EntityExtra`. See below for more details.

2. **IMPLEMENT_CONTROLLER_TYPE_WITH_PY_FACTORY(CLASS_NAME, DOMAIN)**

   This macro declares that the controller will be instantiated using an automatically generated `addControllerClassName` method in Python. The `ControllerClassName` used omits the trailing word '`Controller`' if it is present (*e.g.*, `TimerController` becomes `addTimer`).

   A factory method has to be created to use this feature. Its declaration goes into the class declaration, and its name is `New`:

   ```
   public:
     static FactoryFnRet New( int userArg );
     PY_AUTO_CONTROLLER_FACTORY_DECLARE( EgController, ARG( int, END ) )
   ```

   This method is implemented in the `.cpp` file:

   ```
   Controller::FactoryFnRet EgController::New( int userArg )
   {
     return FactoryFnRet( new EgController(), userArg );
   }
   ```

When implementing a controller, the `Controller` class exposes the following useful methods:

- **`entity()`**

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Returns an `Entity&` object, referring to the entity that owns this Controller.

For more details on methods exposed by the `Entity` class, see the CellApp C++ API documentation and Client C++ API documentation.

- **`cancel()`**

  Cancels this controller. Call this method only on real entities.

- **`ghost()`**

  Informs the cell to update the ghosted portion of this (real entity) controller.

- **`standardCallback ( methodName )`**

  Calls the 'standard' Controller Python notification method on the associated entity. Standard notification methods have the following Python signature: `def methodName( self, controllerID, userData )`.

23.2.1. Configuring Portal's Permissivity

A `PortalConfigController` configures the portal that its owning entity straddles. It is added with the entity method `addPortalConfig`, and takes the following arguments:

- **`permissive`**

  Boolean value indicating whether the portal allows objects in the collision scene to pass through it.

- **`triFlags`**

  uint32 value for the triangle flags that should be returned on collision tests that intersect the portal when it is not permissive.

- **`navigable`**

  Boolean value not currently used, and which should be set to the same value as the permissive argument.

  In the future, this argument may be used to indicate whether the navigation system should consider the portal to be passable. For now however, the navigation system uses the same flag as the collision scene (permissive). For details, on the navigation system, see “Navigation System” on page 89 .

The controller is cancelled with the Entity method `cancel`, as with other controllers. It is a ghost controller, and therefore the portal configuration is correctly replicated across cells when more than one can see it. It is not however propagated to the client, if required it must be done via script properties or messages.

The direction of the entity to which the `PortalConfigController` is attached must be the same as the normal of the portal that is to be configured, *i.e.*, if the portal runs east-west between two chunks, then the entity must face either south or north, otherwise the portal will probably not be found.

Note

An entity should not be moved while it has a `PortalConfigController` attached, or there may be undesirable results across cells.
If the entity needs to be moved, then cancel `PortalConfigController`, move the entity, and recreate the controller.

To the extent that portals are uni-directional and come in pairs, `PortalConfigController` configures only the portal whose normal faces approximately the same direction as the entity, *i.e.*, the portal in the chunk that is found just in front (10 cm) of the entity's position. Another entity with opposite direction may be created if

a separate configuration is desired for the opposing portal. For most purposes however (*i.e.*, navigation and collision) it is only necessary to configure one portal differently to the default permissive state.

Note

The method `configureConnection` has been deprecated, since it does not work across cells.

23.3. Integrating Entity Extras and Controllers

Entity extras are commonly used to provide a more sophisticated means of instantiating Controllers. They might provide a factory that selects one of several types of Controller to instantiate, or provide a means of limiting the number of Controllers that are instantiated.

To begin exploring this, we implement something similar to the automatic instantiation provided by the macro `IMPLEMENT_CONTROLLER_TYPE_WITH_PY_FACTORY`.

We add an instantiation method called `addEgController` to `EgExtra`, taking an integer user argument:

```
class EgExtra : public EntityExtra
{
  Py_EntityExtraHeader( EgExtra );

public:
  // ...

  PY_AUTO_METHOD_DECLARE( RETOWN, addEgController, ARG( int, END ) );
  PyObject * addEgController( int userArg );

  static const Instance<EgExtra> instance;
};
```

`EgExtra` header file `bigworld/src/server/egextra/egextra.hpp` - Declaration of instantiation method `addEgController`

The next step is to implement the method addEgController. To do so, we need to:

1. Add a macro `PY_METHOD` to declare the Python/C++ binding code.
2. Ensure that the method is being called on a real entity.
3. Instantiate an `EgController`.
4. Add the new Controller to the entity.
5. Return the controller ID.

Note

Most Controllers do not need any more functionality than the built-in Python factory method supplies.
Creating unnecessary `EntityExtra` instances should be avoided, since every declared `EntityExtra` type uses 4 bytes per entity (including ghost entities), even when it is not instantiated.

This will mean the following changes to `EgExtra`:

```
#include "egextra.hpp"
```


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```
#include "egcontroller.hpp"

DECLARE_DEBUG_COMPONENT(0);

PY_TYPEOBJECT( EgExtra )

PY_BEGIN_METHODS( EgExtra )
  PY_METHOD( helloWorld )
  PY_METHOD( addEgController )
PY_END_METHODS()

// ...

PyObject * EgExtra::addEgController( int userArg )
{
  if (!entity_.isReal())
  {
    PyErr_SetString( PyExc_TypeError,
      "Entity.addEgController() may only be called on real entities" );
    return NULL;
  }

  ControllerPtr pController = new EgController();
  ControllerID controllerID =
    entity_.addController( pController, userArg );
  return Script::getData( controllerID );
}
```

EgExtra implementation file bigworld/src/server/egextra/egextra.cpp - Definition of instantiation method addEgController

23.3.1. Restricting the Number of Controllers Per Entity

If you want to restrict the entities to have only one Controller each, then the class `EgExtra` may be changed so that it maintains a pointer to the current Controller, and the method `addEgController` should ensure that the pointer is `NULL` before allowing a new one to be added.

The class `EgController` would then, in its method `startReal`, send its pointer to the class `EgExtra`, and communicate to it that it has been cancelled in its method `stopReal`. The pointer must not be directly set in the method `addEgController`, as it would break the symmetry of the Controller 'owning' that pointer in the `EntityExtra`.

Setting the pointer in the mentioned methods in the Controller works correctly when the entity is offloaded to another cell.

The line to add to method `startReal` would be similar to the line below:

```
EgExtra::instance( *this->entity() ).setEgControllerPtr( this )
```

Note that the object `EgExtra` will be instantiated if it does not already exist.

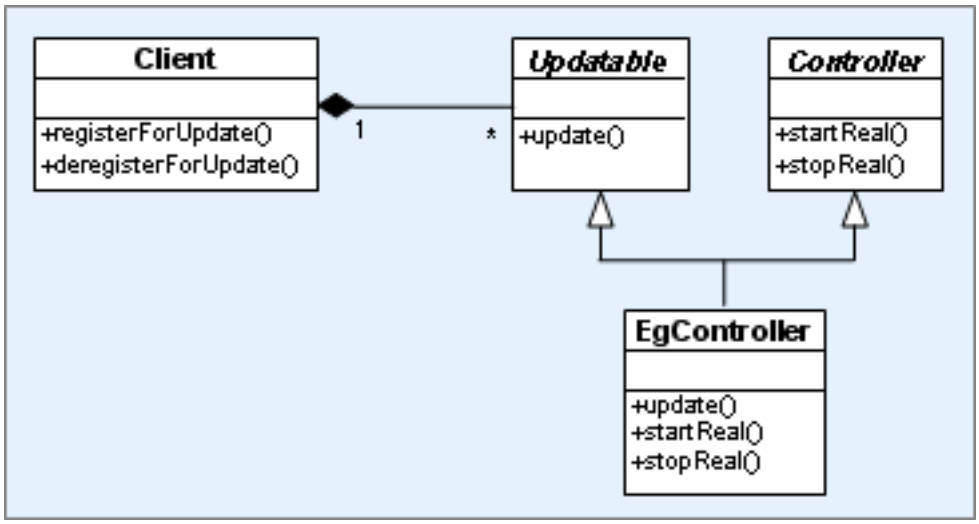
Keeping a pointer to a related Controller can also be useful for an entity extra to maintain states across cell transitions.

For example, to calculate the age of an entity extra, it might provide a method `getEgAge`, and the Controller might store the game time when it is created. The entity extra can then calculate its age by subtracting the current game time from the Controller's stored game time (after checking that the Controller pointer is not `NULL`).

Chapter 24. Updatable Objects

One of the main reasons for using Controllers is to implement in C++ actions that need to occur frequently, thus reducing the execution time in the Python virtual machine on the server. In order to do this, the CellApp has a mechanism to call back certain classes every game tick.

The relationship between the CellApp and its Controllers is depicted below:



CellApp and Controllers

The first step is to add the class `Updatable` to the list of the Controller's base classes:

```
#include "../cellapp/updatable.hpp"

class EgController : public Controller, public Updatable
```

Updates on a Controller are usually run only on the real copy of the entity, and for this reason the class Controller exposes the methods `startReal` and `stopReal` (which can be overridden).

In these methods, the CellApp is requested to start or stop calling back the Controllers. The implementation would look as follows:

```
void EgController::startReal( bool /*isInitialStart*/ )
{
  CellApp::instance().registerForUpdate( this );
}

void EgController::stopReal( bool /*isFinalStop*/ )
{
  MF_VERIFY( CellApp::instance().deregisterForUpdate( this ) );
}
```

We use the macro `MF_VERIFY` in `stopReal` to ensure that an error message is printed on failure - this is an easy place to check for bugs in the Controller.

Now the update method can be implemented to perform any action required on the entity at each game tick.

Chapter 25. Encrypting Client-Server Traffic

BigWorld guarantees the security of the client-server session in two important ways:

- The login handshake is RSA-encrypted using a public key stored in the client resources.
- The client-proxy channel is symmetrically encrypted using Blowfish.

As a result, it is impossible for an attacker to:

- Steal a player's password
- Hijack a player's session
- Inject upstream packets into the player's traffic to disrupt his/her session

25.1. Generating your own RSA keypair

This security framework is provided to work out-of-the-box, and BigWorld ships with an RSA keypair that we have pre-generated for you (`bigworld/res/server/loginapp.privkey` and `bigworld/res/loginapp.pubkey`).

Before making any kind of public game release, it is critical to replace this keypair with a new keypair generated by your own company. As all BigWorld clients receive the same default keypair BigWorld cannot guarantee that this keypair is secure. Generating a new keypair with the `openssl` command-line utility (which should be available in all modern Linux distributions) is simple:

1. Generate a new RSA keypair with with `` `openssl genrsa [numbits] > loginapp.privkey` ``. BigWorld recommends using a 2048-bit key.
2. Strip out the public part of your keypair with `` `openssl rsa -pubout < loginapp.privkey > loginapp.pubkey` ``.

The private key should be placed into your server game resources, and the public part should be placed in your client game resources.

Note

Ensure your private key is never shipped with your game client resources.

25.2. Working with multiple keys

You may want to ship multiple public keys with your game client (for instance, you may want to have a different key for each shard of your game world). The `BigWorld.connect()` function in the Client API allows you to specify which public key to use when logging into the server using the `publicKeyPath` attribute of the `loginParams` object. Please see the Client API documentation for more details.

25.3. Customising the symmetric encryption algorithm

The Client-Proxy Channel is encrypted using 128-bit Blowfish by default. This encryption method was selected as it was the most secure, high-performance symmetric cipher offered in the standard OpenSSL distribution. Should you wish to use a different encryption algorithm, you should be able to edit `src/lib/network/encryption_filter.cpp` to change the encryption algorithm without needing to modify any header files.

You will probably want to leave the stream-padding operations in `EncryptionFilter::send()` and `EncryptionFilter::recv()` as they are; all you should need to edit is the

initialisation method (`EncryptionFilter::initKey()`) and the encryption/decryption methods (`EncryptionFilter::encrypt()` and `EncryptionFilter::decrypt()`).

25.4. How PacketFilters work

In previous versions of BigWorld, encryption support was not automatically provided, and the task of implementing it was left to each individual customer. In recognition of the importance of online security and the sensitivity of game data in today's online games, a standard implementation is now included with BigWorld.

This documentation used to describe the specifics of how to implement your own `Mercury::PacketFilter` to provide end-to-end encryption for a Client-Proxy Channel. A lot of this documentation is now irrelevant, however the description of how PacketFilters work is still accurate and is retained for completeness.

25.4.1. High-level requirements

Packet filters do not allow arbitrary encryption algorithms to be used - the algorithm implemented must work within the mechanics of Mercury. Mercury processes each data packet individually, and has mechanisms for coping with packet loss and similar problems. Since packet filters are called as the last stage of sending a packet, and as the first stage of receiving a packet, algorithms implemented within a packet filter should work under the normal constraints of UDP, which are:

- Packets may be delivered out of order.
- Packets may be delivered more than once.

For this reason, encryption algorithms that assume a continuous transport byte stream are not appropriate. The appropriate encryption algorithms are the ones that work on a single block (packet) at a time within a window, and include algorithms like DES block encryption (as used in the secure PPP protocol), Blowfish, TwoFish, or similar protocols used in wireless Ethernet technology (SSL is not appropriate, since it assumes a continuous stream). The previously mentioned block algorithms can support packet loss and prevent packet replayability, among other features.

Mercury takes care of the particulars of a UDP environment - the packet filter only has to perform its filtering function. It uses sequence numbers of its own to discard duplicate packets (assuming that the packet filter itself has not discarded the packet). It also detects dropped packets, and resends them if they contained reliable information (so the packet filter should not do this). When Mercury needs to resend messages, it will sometimes resend the whole packet unmodified, and at other times (if there is space) it will piggyback just the reliable messages of the dropped packet into the body of the next new packet. Packet filters must be able to cope with both of these types of resending.

Packet filters are always associated with channels, like the ones between a proxy and a client.

25.4.2. Filtering mechanics and requirements

For every sent packet associated with a `Channel` object, the `send` method of the associated `PacketFilter` is called, with the packet as one of the parameters. This happens after all other processing on the packet. Similarly, the `recv` method of the `PacketFilter` instance is called for every packet that is received over the channel by the Nub, before any other processing occurs on it. This method should undo any modifications made to the packet by the `send` method, and then call the base class `PacketFilter::recv` method.

Since packets may be received out of order, the `PacketFilter` instance must be able to reconstruct any packet received within the `Channel`'s window. Duplicate packets may also be received, and these must also be reconstructed when within the window, so that they can be acknowledged (in case the ACK for the original packet was lost).

Note that a `PacketFilter` must not modify a packet to be sent - or at least if it does so, it then must undo the modifications afterwards. If it were to leave a packet modified, and that packet needed to be resent (or

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partially resent), then it would be filtering the data twice. Depending on the nature of the modifications being made to the `Packet`'s data, it may make sense to do the desired changes, or it may make more sense to simply grab a new `Packet` from the `PacketPool`, write the filtered data to that packet, and then send it. This notice does not apply to packets that are received - the `PacketFilter` may modify received packets in-place if it so chooses, especially if it is efficient to do so.

The `PacketFilter` base class' `send` implementation sends the packets over the Nub's socket with the usual accounting, error checking, and retries.

Do not use the Nub's socket directly. The `PacketFilter` base class' `recv` implementation submits the packet for normal internal processing. If you do not call it, then you must give the packet back to the `PacketPool` (with `PacketPool::give`), or the packet will be leaked.

New packets may be obtained and old ones returned at any time via the `PacketPool` object. `PacketFilter` instances may use and store packets for any purpose that they see fit. Also, the `PacketFilter` base class' methods `send` and `recv` may be called as many times as desired from the corresponding derived methods `send` and `recv`, if that is what the filter needs to do.

25.4.3. Extra space for filtering

Normally, when messages are added to a bundle, the full size of the packet may be used. This would deny many potential filtering uses, which might want to add data to packets after this. The virtual method `maxSpareSize` may be implemented in this case to specify the minimum amount of space to leave spare in each packet (*i.e.*, the maximum amount of space required by the `PacketFilter`).

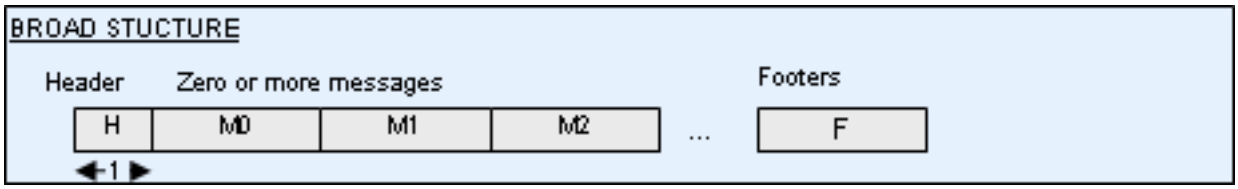
Chapter 26. Mercury Packet Structure

The API for network communications that Mercury exposes is based on a message/bundle paradigm, which masks the true nature of the actual UDP packets being sent and received.

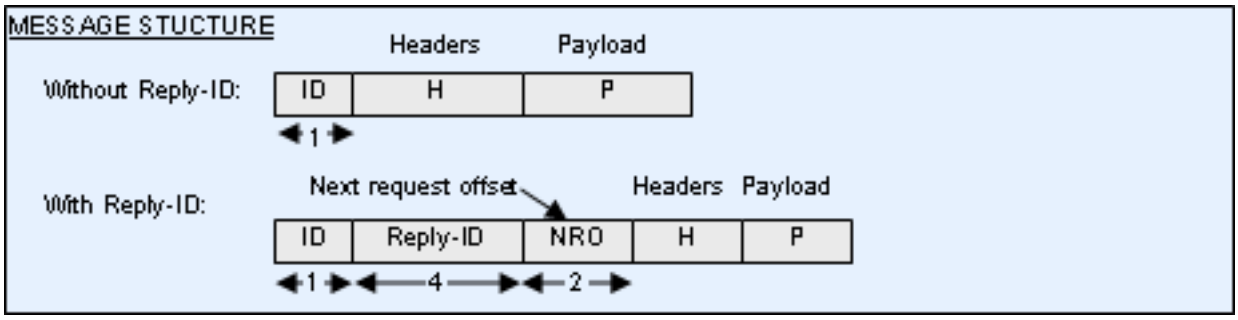
From the programmer's point of view, messages are created and streamed onto Bundles (see `src/lib/network/bundle.hpp`). At some point a Bundle will be sent, at which point Mercury will convert the messages on the Bundle into one or more contiguous sequences of bytes, and send them as a regular UDP packets. This section details the format of those packets.

Broadly speaking, the structure of a Mercury packet is composed of the following:

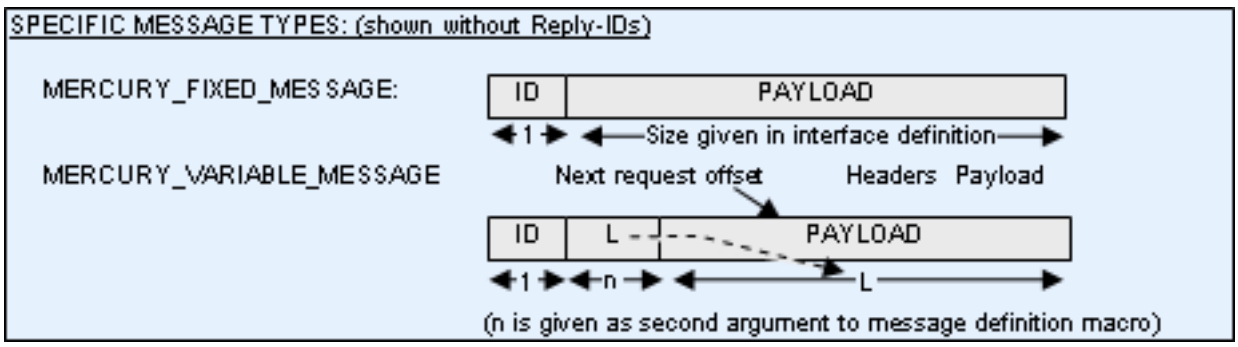
- A single-byte header.
- Zero or more messages.
- The footers specified by the flags in the header.



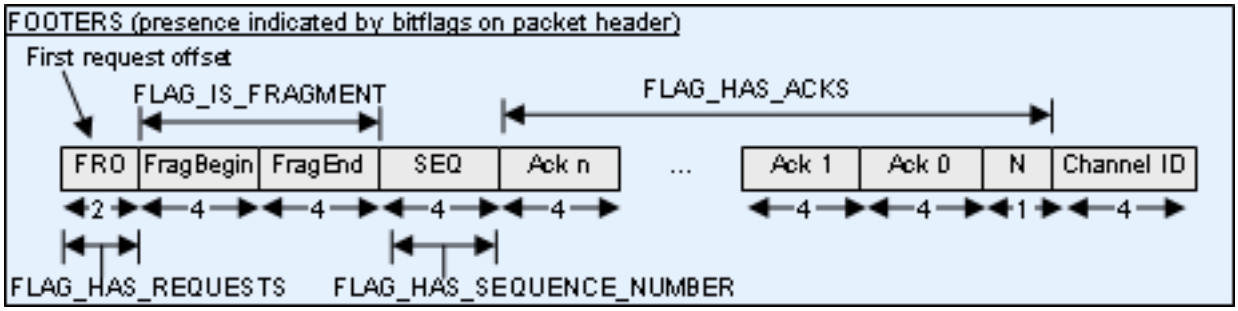
Broad structure



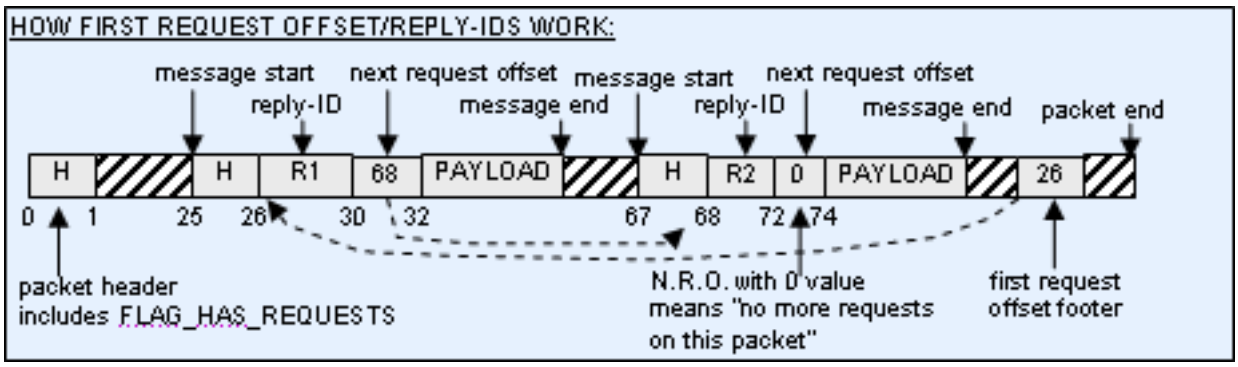
Message structure



Specific message types



Footers



How first request offset/reply - IDs work

26.1. Header

The first byte of a Mercury packet is always a header, which essentially details which footers should be expected on the packet.

It is a bitwise combination of the `FLAG*` constants defined inside Bundle in `src/lib/network/packet.hpp`.

26.2. Messages

The first byte of a message is always its ID.

Looking up that message ID in whichever Mercury interface is currently in effect will reveal what type of message it is and how the subsequent bytes on the packet should be interpreted. For example, LoginApp processes all packets on its external interface according to `LoginInterface`, defined in `bigworld/src/common/login_interface.hpp`.

The ID of a message is the index of its `MERCURY_*_MESSAGE` declaration in the `BEGIN_MERCURY_INTERFACE()` / `END_MERCURY_INTERFACE()` block for that Mercury interface. For example, in `bigworld/src/common/login_interface.hpp`, a login message has ID 0, because it is the first message type declared in the `MERCURY_INTERFACE` block.

There are three basic types of Mercury messages:

- Fixed-length messages
- Variable-length messages
- Multiple-length messages

These types are described in the sub-sections below.

26.2.1. Fixed-Length Messages

A fixed-length message has its precise length determined at compile time. Specifically, it is the second argument to the `MERCURY_FIXED_MESSAGE` macro that declares it.

Therefore, the header of a fixed-length message is simply its message ID. The message payload immediately follows the header, and must have the exact length given in the interface definition.

Although all fixed-length messages are treated equally during low-level Mercury processing, there are different macros that can declare them, which result in different handling in the callbacks that receive the unpacked messages.

The most common example of this is the `MERCURY_STRUCT_MESSAGE` declaration. A message type declared in this way is simply a fixed-length message whose length is equal to the sum of the sizes of the fields of the struct.

The advantage of using a struct message instead of a vanilla fixed-length one is that the object passed to the callback registered for this message type will be an object whose fields match those of the struct. The callback can therefore access them by name, and with the correct types, instead of having to extract bytes at particular offsets and lengths inside the binary data blob, and then cast them to the desired types.

26.2.2. Variable-Length Messages

The header for a variable-length message is the message ID, followed by a short field that specifies the exact size of the message payload.

The length of the field specifying the payload size is the second argument to the `MERCURY_VARIABLE_MESSAGE` macro that declares the message type.

For example, from `bigworld/src/common/login_interface.hpp`:

```
MERCURY_VARIABLE_MESSAGE( login, 2, &gLoginHandler )
```

The length field in a login message header will therefore be 2 bytes long.

26.3. Footers

The footers that are present on Mercury packet are specified by the field header, which is the first byte of the packet, and must appear in a specific order.

They are listed in the following sub-sections in reverse order, *i.e.*, from the end of the packet towards the messages.

26.3.1. Fragment Numbers

If a packet has the header `FLAG_IS_FRAGMENT`, then it is part of a chain of packets where messages span the packet boundaries.

Typically, this will occur when trying to send messages larger than the maximum allowable UDP packet size (*e.g.*, large writes to the database).

The sequence numbers for the first and last packet in the sequence of fragments are written to the footer of every packet in the sequence. Therefore, the footer consists of two 4-byte integers specifying the relevant sequence numbers.

26.3.2. Sequence Number

Given by `FLAG_HAS_SEQUENCE_NUMBER`, this is a single 4-byte sequence number that is streamed onto reliable packets so that they can be acknowledged.

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26.3.3. ACKs

Given by FLAG_HAS_ACKS, these are acknowledgement messages corresponding to sequence numbers from previous outgoing packets.

This is a sequence of 4-byte sequence numbers, followed by a single byte indicating the number of ACKs on the packet.

26.3.4. Indexed Channel ID

Given by FLAG_INDEXED_CHANNEL, this is the channel ID of a packet on an indexed channel, as opposed to a normal channel that is identified by the source address of the packet.

26.3.5. First Request Offset and replyID

When a request is sent to a server component (for example, the LoginInterface 'probe' message, which the server replies to with information about itself) the requester will attach a replyID to the message. The server will attach the same ID to the reply so that the requester can correlate the reply to its original request.

If a message is a request, then an extra field will be added to the packet between the header and the message payload. This extra field is not accounted for by any variable-length fields. The field will contain the 4-byte replyID, followed by the 2-byte offset (from the start of the packet) of the next replyID in the same packet. The reason that the address of the next replyID needs to be specified is so that the replyIDs can be distinguished from regular message payloads and parsed correctly.

If any of the messages on a packet have replyIDs, the header will have FLAG_HAS_REQUESTS set, and the footer will contain the 2-byte offset of the first replyID on the packet. The last request on a packet will have a next-request-offset of 0.

Chapter 27. The Watcher Interface

Watcher is a mechanism that exposes internal operational parameters of a running BigWorld Server so that a developer or administrator can view and change these parameters.

All BigWorld components use the Watcher interface. You can easily extend your own processes to use this interface. To enable this, the targeted server component code needs to be modified-one needs to first register a watcher interface instance, and then specify the internal parameters to be exposed through watchers.

There are a number of watcher types, such as `DataWatcher`, `DirectoryWatcher`, and `FunctionWatcher`, among others. You can build a tree of different type of watchers logically linked together. To do this, you need to first create a new `DirectoryWatcher`, and then add to the tree using the function `addChild()` of the parent watcher. The root of the watcher tree can be obtained by calling the static function `Watcher::rootWatcher()`.

In the case where watchers are attached to the root only, the macro `MF_WATCH` is provided to simplify the process. For more details on adding new watchers, check the existing examples in the server source code and the C++ API documentation.

Once watchers are enabled, the running server process grants access to its internal statistics and debug information.

Background Watcher processes can collect watcher data and republish it through WebConsole's ClusterControl module. WebConsole's StatGrapher module can poll and graph watcher data. For details on WebConsole, see the document Server Operations Guide's section Admin Tools → WebConsole.

27.1. Callable Function Watchers

As of BigWorld 1.9 it is possible to expose both Python and C++ functions as BigWorld Watchers which enables them to be 'called' via the watcher protocol.

When a function watcher has been invoked, three pieces of data will be returned to the invoker:

- Call success status

  This is a boolean True / False representing whether or not the callable watcher successfully completed running.

  A situation that may generate a status of False would be a Python function that throws an exception that is not caught. Such status should be rare, and we suggest that it should only happen during development of the callable functions.

- Function return data

  This is recommended to be a human-readable string, indicating the resulting state/information pertaining to the operation of the called watcher.

  For example, a callable watcher that changes the position of a specific entity number may return *'Entity* `<id>` *moved to (x,y,z).'* on success, or *'No entity with id* `<id>` *found.'* if the entity did not exist at the time of calling the watcher.

- Console output (stdout/stderr)

  This is intended to provide a mechanism for developers writing callable watchers to catch error states and have access to debugging information while development is occurring.

  Any exception thrown in Python scripts will be be in this segment of the return data. Console output may however also be useful for providing more detailed information about a callable watcher operation.

For example, a callable watcher may be defined to display all entities of type `PlayerAvatar`. The Function Return Data piece of data may output *'Found* `<count>` *entities of type* `PlayerAvatar`*'*, while the console output may display summary information for each of the entities.

Callable function watchers can be defined in two ways:

- Via Python code, such as the ones in your game's base or cell entities' resource directories.

  For details on how to implement Python function watchers, see "Implementing Function Watchers" on page 153 .

- Via C++ in server components.

  Currently, C++ support for callable watchers is limited - if you wish to use C++ callable watchers, then please contact BigWorld support for further information on how to use and implement these watchers.

Note

In order to enable any callable function watchers to be exposed on the WebConsole's **Commands → My Commands** page, it is necessary to place the watcher under the `command` watcher path.

27.1.1. Forwarding Watchers

The concept of watcher forwarding was introduced because quite often the knowledge of how best to run a callable function watcher is not known by the person using it - *i.e.*, decisions such as if should all CellApps run the watcher to generate a comprehensive report, or should it be run on the first available CellApp to perform an action.

Watcher forwarding allows a component manager (*e.g.*, CellAppMgr, BaseAppMgr) to forward a callable watcher request to any of its owned components, thus allowing the developer of the callable watcher to determine how best to expose the watchers functionality for general use.

The decision regarding how best to run a callable watcher is encoded by the developer via an exposure hint. Currently there are 2 forms of expose hints:

- Least Loaded:

  Run the callable watcher on the component with the least load of all known components owned by the manager.

- All

  Run the callable watcher on all components owned by the manager.

27.1.2. Implementing Function Watchers

Python function watchers can be added either via a component `PyConsole` for development purposes, or via game script for a persistent callable watcher. Adding a watcher requires using the `BigWorld.addFunctionWatcher` method (for details, see BaseApp Python API documentation, CellApp Python API documentation, or Client Python API documentation).

Generally function watchers are added to pre-existing Python functions which functionality would be useful to expose to a wider audience. Below is a brief example of a function being exposed via a watcher.

```
def addGuardReturnMessage( num ):
   count = 0
```

```
    resultStr = ""
    try:
       count = util.addGuards( num )
       resultStr = "Added %s guards." % count
    except Exception, e:
       print e
       resultStr = "Unable to add %s guards." % num

    return resultStr


BigWorld.addFunctionWatcher(
    "command/addGuards",  2
    addGuardReturnMessage,  3
    [("Number of guards to add", int)],  4
    BigWorld.EXPOSE_LEAST_LOADED,  5
    "Add an arbitrary number of patrolling guards into the world.")  6
```

1 `addGuardReturnMessage` acts as a wrapper function for `util.addGuards`, to provide more meaningful output for WebConsole display.
2 `command/addGuards` is the watcher path the function watcher will be exposed at.
3 `addGuardReturnMessage` is the function name the watcher should call when a request is received at the watcher path.
4 The argument list is defined as a list of tuples, with each tuple containing argument name and the type of the value to be expected.
5 `BigWorld.EXPOSE_LEAST_LOADED` indicates to the component manager to run the watcher request on the component with the lowest load.
6 This is a longer description of the function watcher, which can be useful in outlining any peculiarities or caveats with the function watcher.

More examples can be found in `fantasydemo/res/scripts/base/Watchers.py` and `fantasydemo/res/scripts/cell/Watchers.py`.

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Chapter 28. Debug Message Macros

Debug message macros (defined in header file `src/lib/cstdmf/debug.hpp`) are designed to be used in place of `printf()` for outputting debug information.

The use of debug message macros instead of `printf()` allows for more systematic treatment of debug messages. For example, BigWorld server supports centralised logging and filtering for debug messages.

Before being able to use a debug message macro, you must include one of the following declarations in your .cpp file:

- `DECLARE_DEBUG_COMPONENT( modulePriority )`, or
- `DECLARE_DEBUG_COMPONENT2( watcherLocation, modulePriority )`

The argument `modulePriority` is a number (usually 0) used for filtering debug messages. For more details, see “Filtering by Priority” on page 156 .

These macros also create a watcher entry allowing the modulePriority to be modified. The watcher entry is one of the following:

- `debug/<source_filename>`, or
- `debug/watcherLocation/<source_filename>`

Debug output macros accept the same parameters as `printf()`. The `printf()` function has the syntax below:

```
int printf( const char * format [argument]... )
```

An example usage of a debug output macro:

```
TRACE_MSG( "%s is %d", someString, someInteger );
```

There are several debug message macros, named in the form <priority>_MSG, as described below:

- **`TRACE_MSG` - Priority: 0**

  Tracing program flow, *e.g.*, entering a method.

- **`DEBUG_MSG` - Priority: 1**

  Displaying debugging information, *e.g.*, showing the value of a variable.

- **`INFO_MSG` - Priority: 2**

  Displaying general information, *e.g.*, the start of a process.

- **`NOTICE_MSG` - Priority: 3**

  Displaying information that is more important than INFO, but definitely not an error.

- **`WARNING_MSG` - Priority: 4**

  Displaying potential errors.

- **`ERROR_MSG` - Priority: 5**

Displaying definite errors.

- **`CRITICAL_MSG` - Priority: 6**

  Displaying critical errors (*i.e.*, errors that cause the program to stop running).

- **`HACK_MSG` - Priority: 7**

  Temporary messages used during development. Reserved for BigWorld internal use only.

- **`SCRIPT_MSG` - Priority: 8**

  Messages printed from a Python script. Reserved for BigWorld internal use only.

Debug messages are output to the console on Linux and to the debugger on Windows. For components with access to the game time (such as BaseApp and CellApp), it is automatically added to the start of the message.

28.1. Centralised Logging

In addition to outputting to the console (or debugger), the debug messages are also sent to all MessageLogger processes on the network.

Apart from the filtering options available in MessageLogger, logging (*i.e.*, the sending of messages) to a particular MessageLogger can be disabled by specifying the IP address of the MessageLogger machine in the watcher value logger/del. For details on MessageLogger, see the document Server Operations Guide's section Admin Tools → Logger daemons → MessageLogger.

28.2. Filtering by Priority

The amount of debug output generated by a server component can be controlled through a combination of module priority and filter threshold. A debug message is discarded if its priority is less than the value of variable `filterThreshold` added to `modulePriority`.

The variable `modulePriority` is initialised by the macro `DECLARE_DEBUG_COMPONENT`, but can be later changed using the watcher value `debug/<source_filename>`.

The variable `filterThreshold` is initialised to zero, but can be changed using the watcher value `logger/filterThreshold`.

28.3. Message Priority

All log messages have an explicit priority value. The `DebugMessagePriority` enumeration in header file `src/lib/cstdmf/debug.hpp` defines these values as below:

- **0** - `MESSAGE_PRIORITY_TRACE`
- **1** - `MESSAGE_PRIORITY_DEBUG`
- **2** - `MESSAGE_PRIORITY_INFO`
- **3** - `MESSAGE_PRIORITY_NOTICE`
- **4** - `MESSAGE_PRIORITY_WARNING`
- **5** - `MESSAGE_PRIORITY_ERROR`
- **6** - `MESSAGE_PRIORITY_CRITICAL`

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- 7 - MESSAGE_PRIORITY_HACK
- 8 - MESSAGE_PRIORITY_SCRIPT

This value is used to filter the messages that are printed and sent to the logger. If the message priority is greater than, or equal to the filter threshold value, then the message is allowed. For example, a threshold of MESSAGE_PRIORITY_INFO only allows INFO messages, and higher - which means that TRACE and DEBUG messages will be filtered out.

Chapter 29. Non-Blocking Socket I/O Using Mercury

TCP/IP is commonly used to communicate with 3rd party products, like billing systems, for example. However, care must be taken to avoid blocking the main thread of the program.

One option is to spawn separate threads to handle the I/O, but the recommended option is to use non-blocking I/O. Mercury uses non-blocking I/O by default, and provides callbacks on I/O events to enable the program to wait for something without blocking the main thread.

29.1. Getting Callbacks From Mercury::Nub

The `Mercury::Nub` class contains the main loop of almost all the server executables: `Mercury::Nub::processContinuously()`.

This function effectively time slices the main thread by waiting for events to happen on sockets, and then calling handlers to process those events. It is vital that each event handler does not to block or take significant amount of processing time, otherwise the others will be starved.

The following Mercury::Nub methods allow event handlers to be registered:

- **`registerFileDescriptor`** - `bool registerFileDescriptor( int fd,InputNotificationHandler * handler );`
- **`deregisterFileDescriptor`** - `bool deregisterFileDescriptor( int fd );`
- **`registerWriteFileDescriptor`** - `bool registerWriteFileDescriptor( int fd,InputNotificationHandler * handler );`
- **`deregisterWriteFileDescriptor`** - `bool deregisterWriteFileDescriptor( int fd );`

The `handleInputNotification` method of an `InputNotificationHandler` object registered via `registerFileDescriptor` will be called when the specified file descriptor (usually a socket) has data available for reading.

The `handleInputNotification` method of an `InputNotificationHandler` object registered via `registerWriteFileDescriptor` will be called when the specified file descriptor (usually a socket) is ready for writing. This is useful when writing a large amount of data. A non-blocking write operation will only write an amount of data equal to, or less than, its internal buffers can hold. Then the program must wait until the socket is again ready to be written to. Waiting for a socket to become writable is also useful during the TCP connection process, as the socket will not be ready for writing until the connection is fully established.

All registered handlers must be de-registered using the corresponding function. They are not automatically de-registered when the file descriptor is closed.

For more details, see the example file `bigworld/src/server/baseapp/eg_tcpecho.cpp`.

Chapter 30. MySQL Database Schema

30.1. Entity Tables

Entity tables store the persistent entity data. The name of all entity tables if prefixed by `tbl_`.

Every entity type has one main table and zero or more sub-tables. An entity type's main table is named `tbl_<entity_type_name>`. The main table name is the prefix for the names any sub-tables of that entity type.

For details, see “Mapping BigWorld Properties Into SQL” on page 70 .

30.2. Non-Entity Tables

BigWorld uses a number of tables to keep track of various internal states - these tables' names are prefixed by `bigworld`. Accessing or modifying these tables is strongly discouraged.

BigWorld non-entity tables are described below:

- **`bigworldEntityTypes`**

  Maps entity names to an internal entity type number.

- **`bigworldGameTime`**

  Stores the current game time.

  This information is used during crash recovery.

- **`bigworldInfo`**

  Stores the version number of the schema.

  This number is incremented if a new version of BigWorld uses an incompatible schema that will require migration of data.

- **`bigworldLogOnMapping`**

  Used during the login process to determine whether to allow access to a user.

  For details, see “Bypassing bigworldLogOnMapping and Using Account Entity” on page 116 .

- **`bigworldLogOns`**

  Stores information about entities that are currently active.

  This information is used to construct mailboxes to active entities - every active entity with a non-zero `databaseID` (including non-Proxy entities - will have an entry in this table.

- **`bigworldNewID`**

  Together with `bigWorldUserIDs`, this table is used to keep track of the object IDs currently in use by the system.

  This information is used during crash recovery to prevent allocation of duplicate object IDs.

- **`bigworldSecondaryDatabases`**

Each row in this table represents an unconsolidated secondary database. When the server is shutdown this information will be used by the data consolidation process to retrieve the secondary databases. When the data consolidation completes, this table will be cleared.

For more details about secondary databases, see Server Programming Guide on page 1 's section Secondary Databases on page 80 .

- **`bigworldSpaceData`**

  Together with `bigworldSpaces`, this table contains a backup of the space data.

  This information is used during crash recovery.

- **`bigworldSpaces`**

  See `bigworldSpaceData`

- **`bigworldTableMetadata`**

  Stores meta information about the database schema.

  This table is a candidate for obsolescence, since MySQL already provides APIs for retrieving database meta data.

- **`bigworldUsedIDs`**

  See `bigworldNewID`.

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Part III. Extending WebConsole

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Chapter 31. WebConsole Overview

Although WebConsole provides numerous features to control and monitor a server cluster, there many times when you want to extend its functionality. This part of the document describes how to do that.

WebConsole is built upon an existing web development framework (TurboGears). The list below describes TurboGears' components of interest:

- **TurboGears**

  Rapid web application development framework.

  Component can be found at http://www.turbogears.org/.

  Documentation can be found at http://docs.turbogears.org/1.0.

- **MochiKit**

  A set of JavaScript libraries to enhance existing JavaScript functionality and provide simple mechanisms of performing common JavaScript operations.

  Component can be found at http://mochikit.com/.

  Documentation can be found at http://mochikit.com/doc/html/MochiKit/index.html.

- **KID Templates**

  Template language that provides the ability to integrate Python code into HTML to generate dynamic web pages.

  Component can be found at http://kid-templating.org/.

- **CherryPy**

  Web server component of TurboGears.

  Component can be found at http://www.cherrypy.org/.

  Documentation can be found at http://docs.cherrypy.org/

- **SQLObject**

  Relational database Python wrapper that abstracts database concepts (such as tables, rows and columns) into object-oriented concepts (such as classes, instances and attributes).

  Component can be found at http://www.sqlobject.org/.

  Documentation can be found at http://www.sqlobject.org/SQLObject.html.

The referenced documentation will differ based on the kind of functionality that you are trying to achieve within WebConsole. The sections below outline some common modifications that you might wish to make to WebConsole, and a brief description of what is required. The also include references to the appropriate component documentation that would be used while modifying the tool.

31.1. Adding a Page to a Module

This is possibly the easiest modification that you might want to make to WebConsole.

There are roughly two steps to add a new page:

- **Create a template KID file.**

  This file displays the dynamic content generated in whatever format we choose. The content is generated by the method created in the step below.

- **Add a method to controllers.py.**

  The method will be called when the page is accessed, and generates the content to be passed to the template file.

31.1.1. Create a Template KID File

Below is a simple stub template file that is enough to test if the code is hooked up correctly, before writing the template layout code.

For our example, this template file will be saved as `web_console/log_viewer/ templates/delete.kid`.

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">

<?python
  layout_params[ "moduleHeader" ] = "Log Viewer"
?>

<html xmlns="http://www.w3.org/1999/xhtml"
      xmlns:py="http://purl.org/kid/ns#"
      py:layout="'../../common/templates/layout.kid'"
      py:extends="'../../common/templates/common.kid'">

<div py:def="moduleContent()"> 1

    <script type="text/javascript">
        PAGE_TITLE = 'Delete a Log';
    </script>

    This page will be able to delete logs.

`<p>Page accessed: ${accessTime}</p>
</div>
</html>
```

Example KID template file - `web_console/log_viewer/templates/delete.kid`

1 This tag is necessary because the template inherits its layout from `web_console/common/templates/layout.kid`, which displays the module list in the left hand side of the page, and then fills the main portion of the page by calling `moduleContent()`.

If you remove the `<div>` element and access the page, an exception should be produced, stating that `"name 'moduleContent' is not defined"`.

31.1.2. Edit `controllers.py`

The method created in controllers.py joins the act of accessing a web page in the browser to processing the data and passing it to the template KID file.

An `@expose` decorator must be specified for the method that will tie the template KID file to the new method, with the forward slashes replaced by periods.

Add the excerpt below to the LogViewer class:

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```
# This will only allow users who have logged in to access the page
@identity.require( identity.not_anonymous() )
@expose( template = "log_viewer.templates.delete" )
def delete( self, **kw ):
  return dict( accessTime=time.ctime() )
```

Note that the name of the added method can be accessed directly, since it has been exposed. To access the page, try to connect to http://<machinename>:8080/log/delete.

Finally, if you wish to add the page as a link in the left-hand navigation links, under the module heading, then add the line below in the __init__ method of controllers.py:

```
self.addPage( "Delete Logs", "delete" )
```

Example controllers.py - Addition to the `__init__` method

31.2. Adding a Module

Creating a basic module is a relatively straightforward procedure. Outlined below are the steps required to get a new module working within WebConsole. However, to extend its functionality, it is strongly recommended that you refer to the TurboGears documentation website, and the existing WebConsole modules' documentation.

The Python Console module is the simplest one in WebConsole, and thus the best starting point for grasping how you might extend a module once the basic framework is operational.

The steps below create a module called Devel:

1. Create the folder `web_console/devel` and `web_console/devel/templates`.

2. In each of the folders above, create an empty file `__init__.py`.

3. Add the module to `controllers.py`.

   To make the module accessible from WebConsole, the root controller has to be notified of its existence. To do this, at the end of the `__init__` method of `web_console/ root/controllers.py`, add the excerpt below (you should see similar lines for the other modules above it):

   ```
   import web_console.devel.controllers
   self.devel = web_console.devel.controllers.Devel(self, "Devel Tools",
    "devel","/static/images/console.png", lambda: not isAdmin() )
   ```

   Example `controllers.py` - Addition to the `__init__` method

4. Create the `controllers.py` for the new module.

   Below is an extremely basic stub module that makes the index page available, and links it to the template KID file `web_console/devel/templates/index.kid`:

   ```
   from turbogears.controllers import (expose, validate)
   from turbogears import identity

   from web_console.common import module

   class Devel( module.Module ):
   ```

```
  def __init__( self, *args, **kw ):
    module.Module.__init__( self, *args, **kw )

  @identity.require( identity.not_anonymous() )
  @expose( template="devel.templates.index" )
  def index( self ):
    return dict()
```

Example `controllers.py` for the new module

5. Create the template page to use when the module is accessed.

   Place the text below in `web_console/devel/templates/index.kid`.

```
  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
 "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
  <html xmlns="http://www.w3.org/1999/xhtml"
      xmlns:py="http://purl.org/kid/ns#"
      py:layout="'../../common/templates/layout.kid'">

  <div py:def="moduleContent()">
    The Development Module
  </div>

  </html>
```

File `web_console/devel/templates/index.kid`

After these modifications, the module Devel Tools will be displayed in WebConsole's left-hand navigation menu.

31.3. Add an Action Item to ClusterControl

The action menu supports two types of functionality:

- Redirecting upon selection
- Running JavaScript upon selection

The behaviour is defined in `web_console/common/util.py` script, in `ActionMenuOptions.addRedirect` and `ActionMenuOptions.addScript` methods.

31.3.1. Adding a Menu Item for an Existing Component Type

To add an action menu item to a cluster component type, edit the `web_console/common/caps.py` script, and for the particular cluster process type, add a call to either `addRedirect` or `addScript`.

For example, in order to add a menu item called Clone, which only for CellApps redirects to a different page, the following should be added to the get method in caps.py:

```
if isinstance( o, cluster.CellAppProcess ):
  addRedirect( "Clone", "/cc/clone",
           params = dict( ),
           help = "Clone this process" )
```

Example caps.py - Addition to the `get` method

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31.3.2. Adding a Menu Item for a New Component Type

To enable the detection of a new component process type, it is necessary to add a Python class in `bigworld/tools/server/pycommon/cluster.py` to uniquely identify that process.

In the example below, we add a new component process type for an SMS component, so that WebConsole can display a Send SMS action.

First, a simple stub class for the SMS component must be created. To keep all the different process definitions together, search for the class definition for ReviverProcess, then add the following text just after it:

```
class SMSProcess( Process ):

  def __init__( self, machine, mgm ):
    Process.__init__( self, machine, mgm )
```

Example `cluster.py` - Definition of `SMSProcess` class

The new class then needs to be associated with an MGM message - in `cluster.py`, in the `Process.getProcess` method, edit the `name2proc` hash and add the mapping from the component network name to the class type:

```
  ...
  "client": ClientProcess,
  "message_logger": MessageLoggerProcess,
  "sms": SMSProcess }
```

Example cluster.py - Addition to the `Process.getProcess` method

It is now possible to add an action menu item, just as described in section “Adding a Menu Item for an Existing Component Type” on page 166 .