Meridian 59 Documentation

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Chapter 1

System overview and philosophy

The BlakSton game system is a set of programs used to develop and run a large-scale persistent world. The system consists of a server, a client, and a group of tools. All of the programs run under Win32. At present, the only instance of the system is the roleplaying game Meridian 59.

The server runs at a central location and accepts TCP/IP connections from remote clients. It also runs an interpreter for an embedded language called Blakod, which has been specifically designed for implementing persistent world games. A built-in administration mode allows the server to be remotely configured while it is running.

Players run the client on their local machines and use their username and password to access the server. The client displays a graphical view of the player's vicinity, and allows the player to move, speak, and interact with other objects in the world. The client/server protocol has been designed so that it will use less than 9600 bits per second, a reasonable lower limit for modem users.

The tools consist of a Blakod byte compiler, a room editor, a bitmap compiler, a hotspot editor, and third-party libraries for performing compression and encryption, ftp file transfer, and sound mixing.

The system was designed to support many different games using the same client and server. On the server side, all of the game play resides in Blakod, so that the server itself is independent of the details of any one particular game. On the client side, most of the game-specific interface and data components reside in DLLs outside the main client executable. The client/server protocol is also fairly general, and it can be easily extended.

BlakSton is also meant to be a completely dynamic system. The server can reload Blakod at any time, so that game play can be modified without shutting down the server. In addition, many of the server's configuration options can be changed while the server is running. The server's protocol tables reside in a separate module that can be reloaded at any time. Any piece of the client can be modified by requiring users to download changes. Additional downloadable files can be added while users are still connected.

Security is a serious problem in an online environment. Through a combination of encryption and careful protocol design, the system can prevent the most obvious attacks, and can detect most others. Almost all data from the client is verified, so that a malicious entity should not be able to obtain an advantage in game play, or deny service to others.

Another design goal was reliability, even at the expense of some performance. The server has not experienced a software fault in over 25,000 hours of commercial operation, and there are no known ways to crash the client. Although the Blakod for Meridian 59 contains numerous errors, the server simply reports the errors and continues normal operation. It was the overriding design goal of reliability that allowed the system to become a commercial success.

Meridian 59 is a medieval roleplaying game that uses the BlakSton system. Players try to improve their characters through a combination of combat, magic spells, and teamwork with other players. An alpha version of the game appeared on December 15, 1995, and a commercial version launched on September 27, 1996.

Chapter 2

Architecture

2.1 The server

The BlakSton server is designed to be a generic large-n world game server which could potentially be used for several different online games. Keeping most game-specific code out of the server has made it possible to make a robust server which has not crashed since the system has been commercially available (as of this writing).

In order to make the server incredibly safe, I would estimate that over half of the code is for error checking. For example, even though all Blakod objects' references to other objects are always valid, the return value of `GetObjectByID` is checked against NULL. Instead of using the now-common practice of using assertions to abort a program when unforeseen circumstances arise, the server treats these as possible error conditions and logs the problem, instead of aborting. Since even a single crash could cost hundreds or thousands of dollars of customer service time, this was deemed crucial to the game's success.

Since there is only a minimal amount of game-specific code in the server, the overall design of the server is quite clean (and fairly obvious). The heart of the server is the Blakod interpreter, which runs the actual game code. Blakod calls are made when messages are received from clients or timers expire. Since the Blakod interpreter is single threaded, only one call into Blakod exists at any time. This puts several demands upon the interpreter. First, it must be rather fast, so that the server does not become backed up by client requests. Second, it must endeavor to prevent infinite loops or infinite recursion in Blakod so that one poorly written Blakod function does not hang the entire system.

To support the Blakod interpreter, the server has modules that handle the storage of Blakod objects, Blakod list nodes, Blakod strings, Blakod resources, Blakod strings, Blakod timers, and callback functions. These callback functions, called C code functions, exist so that Blakod may interact with the server, since Blakod has no inherent input or output.

The server's primary task outside of Blakod interpreting is keeping track of network connections made by clients. It needs to verify user logins, allow administration of the game, and parse client messages from the network to send the necessary messages to Blakod.

Client logins are mapped to accounts stored on the server. Each different physical person has his/her own account on the server, which they access by logging in with their own account name and password. Internally, the server stores a unique account number for each account. Each time an account is created, it is given a new account number one greater than the previous largest account number. When an account is deleted, the account number is no longer in use, and unless it was previously the largest account number, is not reused. Since account numbers are 32 bit integers, there is little chance of them ever rolling over.

The server also keeps a map between account numbers and user objects in the game. Each account may have more than one user object mapped to it. When a client requests that it would like to enter the game, the server sends it a list of user objects which it may choose from. This gives the user the option of using any of their available characters in the game each time he/she logs in.

The server maintains and controls all of the state associated with avatar objects. This information is all stored in the Blakod properties of the object. The client knows the avatar's position, associated bitmap files, and a set of properties called "object flags". These flags are used to indicate that the client should display the avatar with special effects, such as invisibility, color translations, or shadowform. The client also knows if the player is paralyzed or resting, so that it can prevent user motion and running, respectively, without a network round trip to the server. The client updates the server's knowledge of a player's position at most once a second, to reduce server CPU usage.

2.1.1 Network interface and threads

The BlakSton Server communicates with other computers using TCP/IP through the WinSock 1.1 interface. WinSock 2 implementations are only now available, and it is not known what benefits the server could derive from using the new WinSock standard.

The server has two threads of execution. The primary thread performs nearly all tasks, including interpreting blakod and parsing messages from clients. The second thread is the interface thread. It runs the window interface and also performs asynchronous input/output on the sockets that the server uses to communicate to clients. The programming overhead of using semaphores to lock access to the server's buffers for client communication is onerous and difficult to maintain. However, it has proven successful. Each time that any thread needs to access either the input or output thread for a socket, it first gets access to the buffer's semaphore, waiting for it to be available if the other thread holds it. The code then reads or writes data from or to the buffer, and then releases the semaphore. This is a standard way for multiple threads in a process to share memory.

The interface thread is quite simple. There is a main loop that dispatches all Window events to the appropriate handler functions. There are several GUI events that are used to provide simple ways to save the game, terminate the server, and bring up an outdated help system. Also, the administrator commands sent by the GUI are passed to the main thread to be handled there.

The only other events that the interface thread receives are events pertaining to sockets. The three different messages are sent when bytes are received, the internal WinSock outgoing buffer changes from a full to a non-full state, or the socket is closed.

When the interface thread receives bytes on a socket, it reads those bytes and adds them to a queue for the appropriate session. A session is a data structure maintained by the server for each connected client. It includes input and output data queues, the session state (whether the client is just logging in, is at the main menu, or in the game), as well as the client's IP address, CPU type, and screen size.

After the bytes are added to the appropriate session's queue, the main thread is signalled. The main thread, when it receives a time quantum, examines each session's queue and proceeds to parse new bytes in each queue.

When the interface thread is notified that a socket's WinSock outgoing queue is no longer full, it looks in the server's outgoing queue for that session. If there are bytes waiting to be sent, then the interface thread immediately sends the queued bytes over the socket and resets the queue.

When the interface thread is notified that a socket has been closed, then the main thread is sent a message to close the appropriate session and free any memory allocated for the session.

2.1.2 Event handling

The previous section describes the window events handled by the interface thread. Here is a description of the events sent to the main thread:

WM_BLAK_MAIN_READ The interface thread sends this when it reads bytes from a client; the main thread responds to this message by parsing the message if it is complete and sending the data to Blakod if necessary.

WM_BLAK_MAIN_RECALIBRATE Sent by the main thread when the timer node in the front of the timer node list changes, so we can reset the time we'll wait for an event. This is only an issue if a new timer is created that is set to go off before any other timer in the system.

WM_BLAK_MAIN_DELETE_ACCOUNT Sent by the main thread when an administrator deletes an account. We handle this by deleting the account.

WM_BLAK_MAIN_VERIFIED_LOGIN Sent by the main thread when the billing system signals a valid login. The appropriate session is then logged in.

WM_BLAK_MAIN_ALLOW_LOGINS Send by the main thread when the billing system is enabled and has finished its initialization. We respond by calling `accept` on a socket to begin to allow client logins.

2.1.3 Communication buffers

Although WinSock has internal input and output buffers for each socket, I chose to implement an additional level of buffering in BlakServ itself. This allows the server to theoretically read and write any length messages, no matter their length, because the server buffers are implemented as a list of buffers. This has not been exploited, but is available.

The buffering system in the server is quite simple. A session buffer list is a singly linked list of `buffer_node` structures, which contains a pointer to a block to send (up to 5000 bytes in length), the actual length of the block, and a pointer to the next node in the list.

To send bytes to a client session, the server calls a function called `SendBytes` with the session structure, buffer, and buffer size to send to the session. `SendBytes` checks to see if the session already has a send buffer list. If the session is backed up, then the new block of bytes is added to the end of the buffer list, and if necessary allocating new buffers on the end of the list. If the session is not backed up, then the bytes are sent straight to WinSock to send to the client. If this call fails, then the bytes are put in a buffer list and stored in the session structure.

Unlike transmitted data, all received data is always placed in a buffer list when it is received by the interface thread. The interface thread then sends a message to the main thread that tells it to process the bytes in the appropriate session.

2.1.4 Blakod interpreter

When a complete message arrives from a client or a timer goes off, the server sends a message to a Blakod object. Client messages are always sent to the Blakod object associated with the client's account, which is always of the class `user` or descends from this class. Client messages can have up to 15 parameters. Timer messages can be sent from the server to any object, and have no parameters.

Parameters are actually referenced as local variables by the compiled Blakod (called *bkod*). If a message gets passed n parameters and uses m local variables, then then local variables $0..n-1$ are actually parameters, and local variables $n..n+m$ are used as local variables.

The core of the Blakod interpreter iterates through the bkod instructions of one message handler. Instructions can only modify local variables for the message handler or properties of the object. The only instructions that can communicate outside of the current objects are CALL instructions, which invoke C code in the server. A complete list of the C functions is in the next section.

Some of the C code functions are quite simple, such as `Bound` which is a combined min and max function. However, most of the C code functions are rather complex and do things that could not otherwise be done in Blakod. The most important may be `Send`. This function takes an object, a message name, and a set of parameter names and values and invokes the Blakod interpreter on the destination object with the given message and parameter values. Since this is implemented as a simple recursive call in the server, the original call is suspended while the sub-call takes place. Also, since the server stack is used for this recursion, there is a check to make sure that the recursion does not go on forever (such as in a Blakod function that was infinitely recursive). If the call stack gets too deep, it is aborted and an error is printed in the error log. If this check did not exist, the server would crash.

The other two critical C code functions are `AddPacket` and `SendPacket`. These functions allow Blakod to build up a packet of data and then send it over the network to a client. `AddPacket` takes an even number of parameters; the odd number parameters must be integers which specify the number of bytes of the following parameter. For example, since many player statistics are known to be small, the protocol only allocates one byte for each statistic. So although object properties and local variables are always four bytes, only the low one or two bytes are sometimes sent, when the protocol calls for it. `AddPacket` takes the values and adds them to a global output buffer. Once a full packet is built up (from one or more

`AddPacket` calls), the Blakod then calls `SendPacket` along with a session number so the server knows which client to send the packet to. The user object is sent this session number each time a client logs in, and stores it for use in calls to `SendPacket`.

`SendPacket` adds a header to the data packet, and checks the output queue for the destination session. If it is empty, the server calls the WinSock send function to instantly send the data to the client. If this fails, it adds the packet to the server's output queue for the session which the interface thread will send later, when it gets a message from WinSock that the send buffer is no longer empty. If the server's output queue is already non-empty, the packet is just added to the queue.

Built in functions

create Takes a class. Creates a new object of the specified class, and sends it the `Constructor` message.

isclass Takes two parameters, an object and a class. Returns the integer 1 if the object is of the specified class or any of the class' descendants.

getclass Takes an object. Returns the class of the specified object.

send Takes an object, a message, and any number of parameters. Immediately sends the given message to the given object, with all of the specified parameters.

post Takes an object, a message, and any number of parameters. Queues up the message in the Blakod message queue. See the next section.

debug Takes any number of parameters. Prints all parameters to the debug log, which is on the BlakServ interface and `debug.txt`.

addpacket Takes any number of pairs of parameters. The odd numbered parameters are the lengths to send of the even numbered parameters. Adds the specified data to a send buffer, which can be sent to a particular client with `SendPacket`.

sendpacket Sends any buffered up bytes (added by `addpacket`) to the given session. The buffer is then cleared.

sendcopypacket Sends any buffered bytes to the given session, while leaving the buffered up bytes in place to be sent again.

clearpacket Clears the buffer of bytes to send to a session (in essense, it cancels any `addpacket` calls since the last `sendpacket`).

getinactivetime Takes a session id. Returns an integer of the number of seconds since the server has received bytes from the session's client.

stringequal Takes two parameters, both of which can be either strings or resources. Returns the integer 1 if the two parameters are different only in capitalization and spacing; otherwise returns the integer 0.

stringcontain Takes two parameters, both of which can be either strings or resources. Returns the integer 1 if any substring of the first parameter differs only in capitalization and spacing from the second parameter; otherwise returns the integer 0.

setresource Takes a dynamic resource (a player's name) and a resource. Sets the dynamic resource to the string value of the resource.

parsestring Takes a string, a debug string (string contained in quotes in Blakod source code), and a message. Calls the C runtime function `strtok` on the string using the debug string as separators, and calls back the calling object with the specified message for each parsed string. Only used for parsing the destination field of mail messages.

setstring Takes a string and a resource. Sets the string to the string value of the resource.

createstring Returns a new, zero length string.

createtimer Takes an object, a message, and an integer number of milliseconds. Adds a node to the timer queue to call the specified message on the specified object in the specified amount of time. Returns the timer id, which can be used in calls to `deletetimer` and `gettimeremaining`.

deletetimer Takes a timer id. Removes the timer from the timer queue.

gettimeremaining Takes a timer id. Returns the integer number of milliseconds before the specified timer is set to go off.

createroomdata Takes a resource, which must specify the filename of a room file. Loads the server movement grid in the specified room file and returns a room id, which as an integer that is different from the room id of any other loaded room.

roomdata Takes a room id. Returns a list of length 3 containing the grid row size of the room, the grid column size of the room, and the security number of the room.

canmoveinroom Takes a room id, a source row and column, and a destination row and column. The destination row and column must specify a square that directly neighbors the source square. Using the server movement grid of the specified room, returns 1 if an object is able to move from the source row and column to the destination row and column; otherwise returns 0.

cons Takes two parameters; the first can be any value, the second must be a list. Adds the first element to the beginning of the list, by creating a new list node.

first Takes a list. Returns the first element of the list.

rest Takes a list. Returns the list without its first element.

length Takes a list. Returns the length of the list. A nil list has length zero.

nth Takes a list and an integer (call it n). Returns the nth element of the list.

list Takes two parameters. Returns a two element list, whose first element is the first parameter and second element is the second parameter.

islist Takes one parameter. Returns 1 if the parameter is a list; otherwise returns 0.

setfirst Takes a list and any value. Sets the first element of the list to be the specified value.

setnth Takes a list, an integer (call it n), and any value. Sets the nth element of the list to be the specified value.

dellistelem Takes a list and any value. Returns the list with the first occurrence of the specified value removed from the list.

gettime Returns the number of seconds since January 1st, 1996.

abs Takes one integer. Returns the absolute value of the integer.

bound Takes an integer (call it n) and two values which can be integers or nil. Call the first of these a and the second b. If a and b are both nil, then this function returns n. If a is nil and b is an integer, then it returns max(n,b). If a is an integer and b is nil, then it returns min(n,a). If both a and b are integers, returns max(min(n,a),b).

createtable Creates a new hash table with 2999 available entries. Returns a table id which uniquely identifies the newly created hash table.

addtableentry Takes a table id, a key value, and a data value. Using the hash function from the ELF file format, calculates the hash value of the key and inserts the key value and data value into the table using open hashing.

gettableentry Takes a table id and a key value. Returns the data value associated with the key value from the specified table.

deletetableentry Takes a table id and a key value. Deletes the data value associated with the key value from the specified table.

deletetable Takes a table id. Deletes the entire table.

random Takes two integers. Returns an integer randomly chosen from the closed interval defined by the two integers.

Objects

The most important data in BlakServ are Blakod objects. They are stored in one large, dynamically sized array of the following structure:

```
typedef struct
{
   int object_id;
   int class_id;
   Bool deleted;
```

```
   int garbage_ref;
   int num_props;
   prop_type *p;
} object_node;
```

Here is what each element of the object node structure means:

object_id This value is the same as the object's index in the object array.

class_id This specifies the class of the object.

deleted This is used by the garbage collector to keep track of which objects are not referenced and need to be deleted.

garbage_ref This is used by the garbage collector to store what this object's new object id will be after the garbage collection is done.

num_props This is the number of properties used by this object.

p This is the actual array of property values for this object.

Initially the array is allocated to store ten thousand objects. However, as the game runs, objects are created, using up this space. Over time, ten thousand objects may not be able to hold every object. In this case, the array is reallocated at twice its previous size. This means that the array is never "full", because even if there are no open entries, it will automatically be resized to store more objects.

List nodes

Another key part of Blakod is list nodes. Although they act much like LISP lists, all operations are destructive–the server itself never makes a copy of changed list. This reduces memory usage considerably, but requires more care on the Blakod programmer's part. They are stored in one large, dynamically sized array of the following structure:

```
typedef struct
{
   val_type first;
   val_type rest;
   int garbage_ref;
} list_node;
```

Here is what each element of the list node structure means:

first This is a Blakod value (4 bits tag, 28 bits data) of the current node in the list.

rest This is a Blakod value of the next node in the list (or nil if it is the end of list). If this is not nil or a list node, then it works exactly like dotted pairs in LISP.

garbage_ref This is used by the garbage collector to store what this list node's new list node id will be after the garbage collection is done.

Resources

Resources are a simple construct used to prevent the server from having to send the actual text of preprogrammed strings over the network every time they are used. They are defined in the resource section of a Blakod source file, and stored in the server in a linked list of the following structure:

```
typedef struct resource_struct
{
   int resource_id;
   char *resource_val;
   char *resource_name;
   struct resource_struct *next;
} resource_node;
```

Here is what each element of the resource node structure means:

resource_id The number assigned to this resource string by the Blakod compiler.

resource_val The string which defines this resource.

resource_name The name of the string, which is used in Blakod to reference the resource.

next A pointer to the next resource node in the linked list.

Strings

Blakod uses strings to represent text data that can change–anything not written by the development team. For example, player descriptions are stored as strings. All player speech is stored as strings, although they use one special string (called the *temp string*) to reduce memory allocations. No strings are created by the Blakod (except by the chess game to store its state). They are parsed from client messages and passed into the Blakod. They are stored in the server as a dynamically sized array of the following structure:

```
typedef struct
{
   char *data;
   int len_data;
   int garbage_ref;
} string_node;
```

Here is what each element of the string node structure means:

data The actual bytes of the string (in ASCII).

len_data The length of the string.

garbage_ref This is used by the garbage collector to store what this string node's string id will be after the garbage collection is done.

Blakod timers

Blakod timers play a large part in programming any game based on the BlakSton system. They are stored in a linked list, sorted by the time they are set to go off (the next timer to go off is first in the list). The linked list is composed of the following structure:

```
typedef struct timer_struct
{
   int timer_id;
   int object_id;
   int message_id;
   unsigned int time;
   int garbage_ref;
   struct timer_struct *next;
} timer_node;
```

Here is what each element of the timer structure means:

timer_id This is a number which is unique among all the timers and can be referenced from Blakod to get the remaining time on this timer or to delete it.

object_id This is the object that will be sent a message when the timer goes off.

message_id This is the message that will be sent to the object when the timer goes off.

time This is the time the timer will go off, measured in milliseconds since Windows started, and hence can be compared to the result of the Windows call `timeGetTime()`.

garbage_ref This is used by the garbage collector to store what this timer's new timer id will be after the garbage collection is done.

next This is a pointer to the next timer node in the linked list of Blakod timers.

Blakod can control timers with the `CreateTimer()`, `GetTimeRemaining()`, and `DeleteTimer()` calls, as described in the previous section.

The main loop of the server operates in the obvious way with Blakod timers. At the beginning of the loop, it checks the timer list to determine the amount of time until the next timer is set to go off. It then waits for events (network events sent by the interface thread) for up to that period of time. If it receives no events, it removes the timer from the timer list, and calls the specified Blakod object with the specified message, which handles the timer. After the Blakod call is returned, the main loop starts again, calculating the next timer and waiting for an event.

System timers

BlakServ has a number of system timers, which are activated on a periodic basis. Every time the main thread gets a network related message from the interface thread, it checks to see if any system timers are ready to go off, and if so, performs the appropriate action.

Unlike Blakod timers, system timers are not created and deleted. They are created once when BlakServ starts, and are never deleted. The following list describes the various system timers (by their symbolic names used in the server).

SYST_GARBAGE Performs garbage collection.

SYST_SAVE Saves the state of the game to disk.

SYST_BLAKOD_HOUR Sends the system object a message saying that a game hour has elapsed.

SYST_INTERFACE_UPDATE Sends a message to the interface thread to update the statistics on the user interface.

SYST_RESET_TRANSMITTED Resets an internal count of the number of bytes written to the network since the last time the count was reset.

SYST_RESET_POOL Frees buffers used by the network buffering system.

SYST_CHECK_PORTAL If the billing system to communicate billing information to an outside program is enabled, this checks to make sure the TCP/IP socket used for communication is still active. If it is not, it attempts to reconnect to the outside program.

Blakod message queue

The Blakod message queue is implemented by a small bit of code I wrote one afternoon in March 1996. The problem that we faced was quite disturbing–NPC characters were responding to player speech before the speech was sent to everyone in the room! What happened was that when a player sent a `BP_SAY` message, the room object send a `SomeoneSaid` message to every active object in the room. If an NPC was before a player in the room list, then it would see the speech and respond to it to every active object in the room. After this, the original text would then be sent to the rest of the active objects in the room.

At that point, there was only one top-level message being interpreted at any time. The top-level message (called directly by the server) may send other messages, but when the original top-level message returned, control returned to the server which returned to the main loop.

To solve the speech problem, I created the Blakod message queue. When the original top-level message is sent, the queue is empty. While the server is interpreting Blakod, it can call `Post()` which adds an element to the Blakod message queue. When the top level message returns, the server enters a loop that dequeues an element from the Blakod message queue and sends the indicated object the appropriate message. This is done until the queue is empty.

This solved the NPC speech problem nicely. When an NPC gets a message from a player that it wants to respond to, it posts itself a message, which gets dealt with after all the players in the room hear the initial player speech.

The Blakod message queue is a queue of the following structure:

```
typedef struct
{
   int object_id;
   int message_id;
   int num_parms;
   parm_node parms[MAX_NAME_PARMS];
} post_node;
```

object_id The object to send a message.

message_id The message to send to the object.

num_parms The number of parameters being sent.

parms The actual values of the parameters being sent.

Garbage collection

The garbage collection system exists in BlakServ to reclaim memory wasted by objects, list nodes, and strings that are no longer needed in the game. Without garbage collection, any machine running BlakServ would run out of memory in a matter of days. With garbage collection, BlakServ is able to run for weeks at a time without needing to be stopped and restarted.

BlakServ uses the "stop and sweep" garbage collection strategy, which means that for a fraction of a second the server stops all processing, performs garbage collection, and then resumes normal operation. Garbage collection is performed in several stages. The first stage reclaims list nodes, the second stage reclaims objects, and the final stage reclaims strings.

The garbage collection system uses the `garbage_ref` field of the various structures as temporary storage to keep track of which structures are referenced and what their new id will be after the garbage collection is done. The list node garbage collection starts by traversing every property of every object and marking every list node referenced by a property. Each list node that is referenced is then given a new list node id in its `garbage_ref` field. All objects are again traversed, and any references to list nodes are changed to refer to the new list node's new id. Then, the list node array itself is compacted, so that unreferenced list nodes are deleted and all list nodes have their new list node id. One important thing to note about list node garbage collection is that there is a flaw–objects that are later cleared in object node garbage collection may reference list nodes and these list nodes will be saved, even though they could be erased.

The garbage collection of objects works in a similar fashion. It is slightly complicated by the fact that objects are referenced by more places in the server than list nodes. Object node garbage collection begins by traversing the objects associated with every user account in the system. Every object referred to by a property of a user object is marked as referenced and then recursively checked itself–any object referred to by their properties is marked, etc. If a property is a list node, then the list is traversed and any objects referred to by the list are marked and then checked themselves. The system object is also automatically marked and traversed. In this way, every object that is still used by the game is marked as needed, and all unreferenced objects can be prepared to be deleted. No Blakod messages are sent during garbage collection to garbage collected objects.

The garbage collector next goes through every object and gives all marked objects a new object id in the object's `garbage_ref` field. It then proceeds to traverse every property of every object, every list node, user account, session, and timer and replaces any object id with the new post-garbage collection object id. Then, the object node array itself is compacted, so that unreferenced objects are deleted and all object nodes have their new object node id.

String garbage collection works much the same way. First, every property of every object is traversed, and all strings that are referenced are marked. All list nodes and other objects referenced by each traversed property are recursively traversed, thereby marking all strings referenced by any object or list node in the system. Each marked string is then given a new string id which is temporarily stored in each string node's `garbage_ref` field. Each object and list node is traversed and all references to strings are changed to refer to the string's new post-garbage collection id. The string nodes are then traversed and non-referenced string nodes are deleted.

Timer garbage collection works much the same way, although it is a bit simpler. Timers aren't garbage collected, because they are automatically deleted when they go off. At garbage collection time, each timer is given a new timer id. The lowest id timer becomes timer id 0, and each timer is given a new id one larger than the previous timer's id. Then, each object and list node is traversed and timer id's are changed to the new id. This allows timers to be freely used in Blakod without the fear that timer id's could rollover 28 bits and cause problems.

As described earlier, BlakServ was designed to be a very stable server. In order to prevent crashes, many checks are performed on function return values which should be guaranteed. For example, in the garbage collector, for every list node that is attempted to be traversed, the list node id is checked to be valid. If a list node that is referenced does not exist, a "death by garbage collection" error is printed, and the server does not crash. However, with a serious error such as this, objects will be left with invalid references, which may cause the game not to function, depending on the specific Blakod. Checks are performed on objects, list nodes, strings, and timers, and all could report an error. Invalid references can only exist if there is a serious bug in either Blakod or BlakServ. Correct code will not generate these types of errors.

Optimizations and bottlenecks

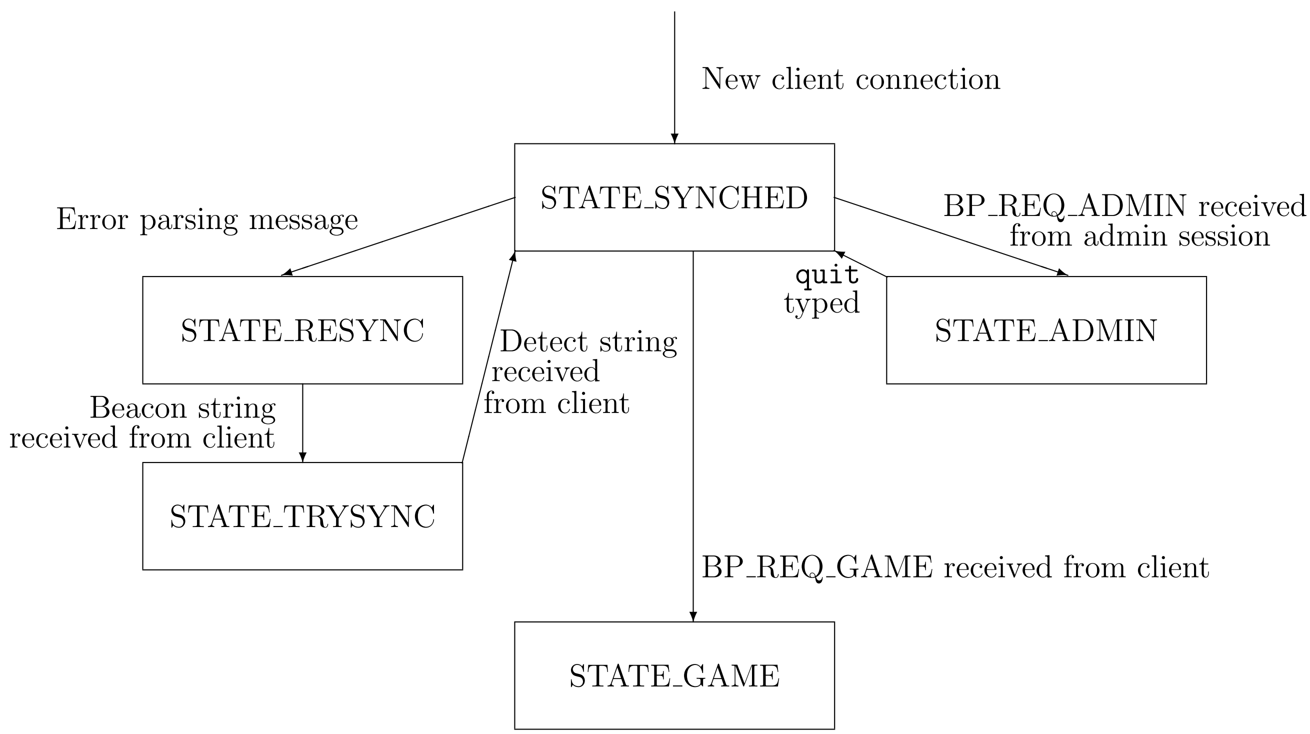
Blakserv was designed to be limited in performance only by the CPU power of the machine it runs on. In other words, given any reasonable network connection and any type of connections to client machines, the number of clients that the server can handle at one time is limited only by the speed of the server CPU. We believe that the server spends most of its time interpreting Blakod. Therefore, the obvious place to try to improve the server would be the Blakod interpreter. This would give the best cost/benefit ratio of any work done to optimize the server.

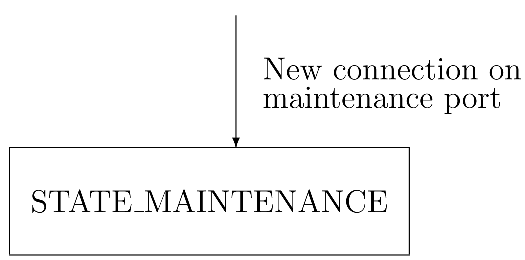
I performed some profiling tests on the server in the summer of 1995 which allowed me to increase the server performance by about 50% on a Pentium class machine. I achieved these gains by inlining the `RetrieveValue` function, changing a linked list of all loaded Blakod classes into a hash table, and giving the class structure a pointer to its parent class, rather than just the parent class id.

At this point in the evolution of Meridian 59, the Blakod interpreter is quite efficient; I do not believe that much performance could be gained by changing the server algorithms. Rewriting the main interpreting loop in assembly might give a reasonable boost in performance. However, there is a large amount of Blakod that has been written with little regard to performance. Several performance critical messages (those dealing with player motion) could most likely be analyzed and simplified to make the server able to handle more users.

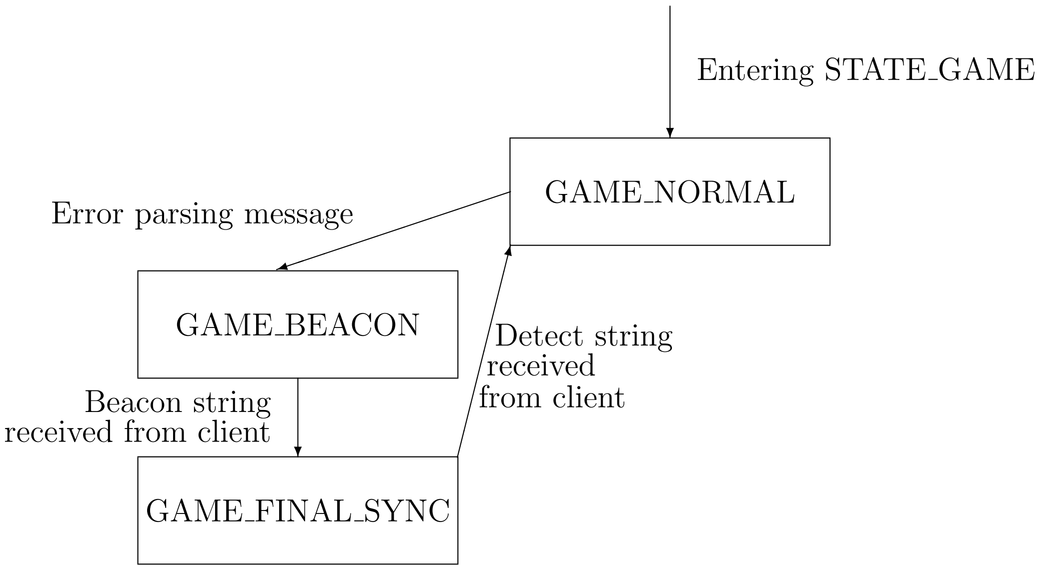
State diagram

The following diagram shows the possible states and state transitions for each connected client. The second diagram shows the substates and substate transitions while in STATE_GAME. Note that STATE_RESYNC, STATE_TRYSYNC, GAME_BEACON, and GAME_FINAL_SYNC are not necessary since we communicate with clients using TCP, a reliable protocol. They exist because communication over serial ports was supported for the first year the system existed, but has since been removed.


New client connection
STATE_SYNCHED
Error parsing message
BP_REQ_ADMIN received
from admin session
STATE_RESYNC
quit
typed
STATE_ADMIN
Detect string
received
from client
Beacon string
received from client
STATE_TRYSYNC
BP_REQ_GAME received from client
STATE_GAME


New connection on
maintenance port
STATE_MAINTENANCE

STATE_GAME Substates



Memory usage

The server allocates and frees a good deal of memory over the course of time. These allocations are tracked by a number of categories in order to track down memory leaks without too much effort. Any administrator can see the current totals with the admin command `show memory`. Much more memory is used to store the game objects and list nodes than anything else.

Here are the memory categories:

Timer Blakod timer nodes.

String Blakod strings.

Kodbase The symbolic names of resources (read from kodbase.txt).

Resource The resource nodes themselves.

Session Session nodes.

Account User account information.

User User to game object mapping information.

Motd Message of the day.

Dllist DLlist nodes which store filenames to send to clients for updates.

LoadBof Nodes which point to loaded compiled Blakod.

Systimer System timer nodes.

Nameid Mappings of class ids and message ids to their Blakod names.

Class Class nodes for each Blakod class.

Message Message nodes for each message in each Blakod class.

Object Blakod object nodes.

List List nodes.

Object properties The properties of each Blakod object.

Configuration The hardcoded configuration options.

SMTP Memory used by current email account creation/deletion connections.

Rooms The movement grids of loaded room files.

Admin constants Name constants usable in admin mode.

Buffers Communication buffers.

Game loading Used while loading a saved game.

Tables Blakod hash tables.

2.2 The client

2.2.1 Control flow and event handling

As described in section **??**, the client has its own internal message system that it uses to pass events to a set of *modules*, or Windows DLLs. In fact, when the client starts up, one of the first things it does is load a module called `intro.dll`. In the case of Meridian 59, this module displays a corporate logo and then a splash screen for the game. When the player clicks on a button on the main window, the module unloads itself.

The client has a structured system for handling Windows messages. Each incoming message is sent to a handler function, which then dispatches the message according to the state the client is in. The state is a single variable that can assume one of several values (see section **??**). Each state has an initialization function that the client calls when it enters the state, and an exit function that it calls when leaving the state.

Modules may call any of over 100 functions that the client exports to them. Thus, in many cases, control passes from Windows, to the client, to a module, and then back to the client. It is also possible for modules to communicate with each other directly, although this feature is not currently used.

The client can tell which objects are players via the object flags that are associated with each object in protocol messages from the server. There is a bit reserved in the object flags bit vector that indicates that an object is a player. The client cannot tell which objects are “NPCs” (a term without meaning in Blakod). However, object flags indicate which objects are attackable, and which are legal targets of offer and buy commands; this usually distinguishes animate objects from inanimate ones.

Windows sockets

When data is ready to be read from the socket connection to the server, the client receives a Windows message. The client then retrieves all the available data and places it in a buffer. Because BlakSton uses TCP, boundaries between client/server messages may not match boundaries between TCP segments. Thus, the client checks to see whether it has a complete protocol message each time it receives data over the socket. If so, the message is parsed and sent to an appropriate handler function. The client also handles cases where a single TCP segment contains multiple protocol messages.

The call to open a socket connection to the server is done asynchronously, so that the user can abort it if it takes too long. However, the DNS lookup of the server's IP address is still done synchronously.

Keyboard handling

The standard Windows keyboard messages are not really sufficient for use in a serious game. For one thing, key down messages aren't always matched with a key up message because of dialog boxes appearing and disappearing, and there is also a flaw in the reporting of key states with the Num Lock key. Therefore, when the client receives a key down message, it begins polling the keyboard once per frame. The state of the entire keyboard is read, and special code gets around the Num Lock problem.

The number pad keys generate different key code values depending on whether the num lock toggle is on. Due to an apparent bug in Windows, when a key is pressed, num lock is toggled, and then the key is released, the key up code is not always the same as the key down code. The special num lock handling code synthesizes an up message for all of the number pad keys whenever any key is released. Without this, the original number pad key would remain down, which causing the player to spin out of control, since these keys are used for movement and turning.

Each key, along with the state of each of the modifier keys (Shift, Ctrl, Alt) may map to a user action. The mapping of key states to action is stored in key tables. Each client game state has a list of key tables associated with it, and calls exist for modules to add and remove their own key tables. Thus, the client itself doesn't contain any information about the actions bound to keys. The one exception is the F1 key, which is bound to running the Web browser on the Meridian help files. This key is handled as a special case so that the F1 key provides help anytime the client is running (not just when the client is in the game state).

Some user actions, like moving and turning, can occur once per frame, while most others should only repeat at a certain maximum rate. Further, only one motion and one turning action should be allowed per frame, so that players can't move faster by just holding down more keys. The keyboard handler handles move and turn actions differently from other actions to account for these game play considerations.

Animation

When the client is the foreground application, it renders a frame each time Windows notifies it that its event queue is empty. This ensures that rendering occurs at the fastest possible rate. However, when the user moves the client to the background, it makes sense to free some CPU time for the new foreground task. Windows also stops delivering idle notification messages to the client when it moves to the background, or (inconveniently) when a menu or dialog pops up.

To get around these problems, the client starts a timer when Windows informs it that idle messages would no longer be delivered. This timer goes off ten times a second; when the client receives a timer message, it renders a frame. Thus, the game animates its 3D view at a reasonable rate while allowing external programs to run with reasonable performance on most machines.

The client builds up an avatar graphic image from a base bitmap and a set of overlay bitmaps. The base bitmap is the torso for players; all other bitmaps are placed relative to the torso. As described later, each bitmap has a set of associated hotspots, where overlay bitmaps are placed. Overlays are drawn before bitmaps with negative hotspot numbers, and after overlays with positive hotspot numbers. Overlays can have a maximum depth of 2; that is, overlays on overlays are allowed, but overlays on overlays on overlays are not. Given the base bitmap and two levels of overlays with positive and negative hotspot numbers, there are effectively seven possible layers in an avatar image. The client iterates over the list of avatar bitmaps seven times, from bottom to top, in order to draw the bitmaps that make up a player in the right order.

2.2.2 Graphics engine

The graphics engine is very similar to that of DOOM. The world is a 2D extruded model, meaning that each point can have an independently set floor and ceiling height, but no point can have two floors directly on top of each other. Geometry is represented by a binary space partitioning (BSP) tree, which the engine uses for determining polygon drawing order. The basic elements of the BSP tree are walls, which are always vertical, and sectors, which describe the floor and ceiling of a convex region. Each wall references up to two sectors, one on each side. The wall is directed so that it has a positive and a negative side, as in the standard BSP traversal algorithm. Each wall and sector also contains information about how to render itself on the screen, such as texture references, texture offsets, and animation information.

The entire game world is divided up into a series of *rooms*. Each room has an associated room file on the player's disk. The file contains a representation of the room's BSP tree, which the client loads when the player enters the room. During loading, all numerical references are converted into pointers for speed during drawing. The client also loads all the textures for the room into memory at this point.

Information about objects in the room arrives in a separate message from the server. Each object can have an associated bitmap and a location in the room. All objects are flat 2D sprites that are always parallel to the viewing plane.

Drawing a frame

At the start of a frame, initialization code sets up viewing parameters based on the player's location and viewing angle. Having the player look up or down is accomplished by simply shifting the horizon down or up respectively.

Objects and projectiles are first inserted into the leaves of the BSP tree corresponding to their locations. This is done by descending the tree from the root for each object, and determining whether the object is on the positive or negative side of the wall in the current BSP tree node. When the client reaches a leaf of the tree, it adds the object to a list of objects in the corresponding sector.

To draw the scene, the renderer walks the BSP tree in postorder (front-to-back) fashion, at each step choosing the child on the same side as the viewer. Each node of the tree contains a bounding box used for clipping; if no part of the bounding box is visible, the node is immediately skipped, and its children are not traversed.

As each wall or sector is encountered during the tree traversal, its screen extent is calculated and added to a global *draw list*. The screen extent of any wall, floor, or ceiling is always a quadrilateral with two vertical edges, a shape the engine calls a *cone*. Initially, the entire screen is kept as a single cone, representing the unfilled areas. As walls, floors, and ceilings are encountered, their screen extents are removed from the unfilled cone list, and world elements that are encountered later clip to the unfilled area. Thus, each screen pixel is drawn at most once (excluding sprite objects).

Objects are transparent 2D sprites; they are added to the draw list as they are encountered as part of traversing their containing sector. Since they are transparent, they have no effect on occlusion.

After the tree traversal is complete, the renderer walks the draw list and actually draws each element. Drawing walls, floors, and ceilings is done with standard affine texture mapping techniques. Drawing objects may involve also drawing associated overlays, or using special effects such as invisibility. At base, though, drawing an object is a simple matter of scaling a bitmap.

The unfilled area of the screen is then filled with the current background bitmap, or solid black if there is no background. As an optimization, if there were more unfilled cones than a certain threshold on the previous frame, the background is simply copied to the frame buffer before any other rendering takes place. This avoids the overhead of cone calculations when there are many unfilled cones.

There are three elements to lighting: ambient lighting, sector lighting and depth cueing. Each room has an ambient light value, which by default is used as the light level of everything in the room. In addition, each sector can have its own light value, and it can choose to either use this light value all the time, or to add it to the ambient light. There is also an additive light source at the player, which causes closer objects to appear brighter (depth cueing). Walls are drawn with the same light level as their adjacent sectors.

The client renders into an area of system memory, which is copied to the screen when the frame is complete. Users have the option of selecting a 2:1 stretch of the scene before it is copied to the screen. When this option is turned on, the scene is first stretched by a small assembly language routine into a larger area of system memory, and then this area is copied to the screen.

Animation

Whenever the client has no Windows messages pending, it starts drawing another frame. The first thing that happens is that all parts of the world are given a chance to animate.

Objects can animate by moving and by changing one or more of their associated bitmaps. For example, when a player starts walking, the client sets up motion between the player's starting and ending points, and also sets up the player's overlays so that the legs and arms move. Each time a new frame is drawn, the client updates the player's position, and potentially its arm and leg bitmap frames. The client keeps track of the amount of time between frames so that animation is smooth even when the frame rate is variable.

Wall, floor, and ceiling bitmaps can also animate in the same way as object bitmaps. Other animating elements include sectors that move up and down, textures that scroll, and blinking sector lights. Each of these elements carries out a particular animation when it's time to draw a new frame.

2.2.3 Modules

A module is a Windows DLL that the client loads in response to a message from the server. When loaded, each module registers its interest in receiving certain types of events from the client. As events occur, the client passes them to interested modules; each module may optionally handle the message and prevent it from being passed to any other modules.

When the client takes an action that may be of interest to a module, it scans all the currently loaded modules, and passes the event to any module that had registered interest in this event type. The module's event handler can return False to indicate that the client should not pass the event on to any other modules. In addition, this return value often causes the client itself to stop any further processing of the event. Thus, a module could in theory override virtually all of the client's default behavior and replace it with other behavior.

The interface between the client and its modules consists of the event handlers in the module, two procedures in the module that are called at load and unload time, respectively, and the client procedure that passes events to modules. In addition, the module can call any exported client function, of which there are over 100.

Much of the client's interface and many of its dialogs are handled by modules. The following is a list of all the current modules and their functions. The possible event types are listed in Appendix **??**.

`char.dll`

Contains the character selection creation dialogs. This module is loaded as the player enters the game. After the player selects a character, the module is unloaded.

`mailnews.dll`

Contains the dialogs for reading and writing mail and news messages. It's loaded after `char.dll` is unloaded.

`merintr.dll`

Contains large parts of the interface, such as the inventory and statistics display areas. The module also handles many server messages and contains tables for mapping keys to actions.

`intro.dll`

Contains the introductory logo sequence that's displayed when the client starts up. The name of this module is hard coded into the client, since it's loaded before the client has connected to the server.

`admin.dll`

Contains the administrator mode dialog. The server only instructs administrator accounts to load this module.

`dm.dll`

Contains handlers for the DM text commands. The server only instructs DM accounts to load this module.

`chess.dll`

Contains the dialogs for the chess game. The module is loaded when a player starts a chess game, and is unloaded when the player leaves the chess game.

Since modules can override almost all default client behavior, they allow the same core client to be used with multiple games. In its current state, the client still contains some game-specific code, such as the graphics engine and a few interface pieces. These would either need to be rewritten, or moved out to a module in the implementation of a new game.

Most of the client/server protocol is fairly game-independent, so the default client handling of most protocol messages could work with many games. Those messages that need to be changed could either be replaced, in which case the client's default behavior would never be invoked, or a module could intercept the message as it arrives and override the client's behavior.

2.2.4 State diagram

Parts of the client are organized into a finite state machine (see Figure **??**). Each state can optionally take action when the client enters and leaves the state. For example, when the client enters `STATE_TERM`, it creates windows for the administrator mode interface, and when it leaves the state, it destroys the windows.

A second finite state machine operates when the client is in `STATE_GAME` (see Figure **??**). During normal game play, this machine is in the state `GAME_PLAY`. The `GAME_SELECT` state handles interface behavior when the player is selecting a target. When the server garbage collects, it sends a **BP_WAIT** message to the client, telling it not to accept any user input until a **BP_UNWAIT** message arrives. This causes the client to move to the `GAME_WAIT` state, which blocks user input.

Figure 2.1: State diagram for the client.

Figure 2.2: State diagram for the client while it is in the main state `STATE_GAME`.

2.2.5 Memory usage

The parts of the client that use the most memory are the frame buffers, the current room's BSP tree, and the bitmap caches.

The main frame buffer is 452 by 276 pixels, and the larger buffer for stretched images is twice as large in each direction. Together, these total 600 kilobytes of memory, which is allocated when the client enters the game.

The size of the BSP tree in memory varies widely depending on the size and complexity of the room. Current rooms use up to approximately 300-400 kilobytes of memory.

The client allocates most of free memory to bitmap caches, one for textures, and one for all other bitmaps. First the client determines how much free virtual memory is available, and truncates this amount at a maximum of 60 megabytes. Then it estimates the size of the operating system in memory, and sets aside 75% of the remaining amount for the object bitmap cache, and 25% for the texture cache. When a bitmap is loaded or accessed, it is added or moved to the front of the cache's bitmap list; when the cache is full, bitmaps are removed from the back of the list in least recently used order.

Other pieces that use substantial amounts of memory are the draw list in the graphics engine, and Windows objects such as fonts, windows, dialogs, etc.

2.3 Dynamic updates

Any part of the client installation can be dynamically updated, even while the server is still running. Updates are done via ftp using Microsoft's Wininet DLL. The ftp server machine need not be the same as the game server machine; it is settable in the server's configuration file. To help transfers go faster, update files are compressed with Crusher and decompressed after they are received.

Immediately after logging in, the client sends its version number to the server. If the client is out of date, the server tells the client where to retrieve a new version. The client then spawns a separate program called `club`, passing it the ftp server and filename to download on the command line. `Club` retrieves the new client version via ftp, decompresses it, and runs the new version.

The client's INI file contains a sequence number called the *download time*, which identifies the latest data file update the client has received. When the client enters the game, it sends its download time to the server; the server compares the time with the value in its configuration file. If the client's download time is less than the server's configured value, the server sends instructions on how to update the client's data files.

On startup, the server reads a text file called `packages.txt`, which contains a line for each action the client should take to update its download time. Each line of the file contains a download time, a filename, and an integer which acts as flags, separated by spaces. For each download time greater than the client's value, the server sends these three fields in a message to the client. The client interprets the flags field as a particular action to take, and when this action is complete, it updates the download time in its INI file. Assuming that all actions complete successfully, the client tries to enter the game again; since its download time is now synchronized to the server's value, it succeeds.

The flags field of a line in `packages.txt` can instruct the client to download or delete a file, and which directory the file appears in. The various flags values allow the client to update files in any of its subdirectories, so that any data file can be updated.

One particular value of the flags field indicates that the client should download a new banner advertisement graphic. Normally, as the client downloads files, it displays its progress in a dialog box to the user. However, to avoid giving the appearance that the game play is being updated when only advertisements are changing, the client instead displays a small message dialog as a decoy when all of the files it needs to update are advertisements.

All of the settings related to updates in the server's configuration file can be changed dynamically, and the `packages.txt` can also be edited and reloaded while the server is running. Thus, any part of the system can be updated without taking down the server.

2.4 Security considerations

Room and resource files are encrypted on client machines, so that players cannot read or modify them. Each room file also contains a checksum that the client verifies when it loads the file, to make sure it hasn't been modified. As a final precaution, the client sends this checksum to the server when it loads the room, and the server verifies that the client has actually loaded the correct file. This prevents players from switching room files. Other file types, such as graphics, sound, and music, are stored unencrypted, because players cannot gain an advantage by modifying them.

User passwords are run through the MD5 one-way hash function algorithm before they are sent to the server; thus, passwords never appear in plaintext on the network. The server stores the hashed passwords in its account file, so that even the theft of the account file will not compromise any user accounts.

To prevent players from replaying packets, the protocol contains a small amount of state. When the client first connects, the server sends it seeds for 5 pseudorandom number generators. Each time the client sends a message, it includes the output of one of the generators. The server verifies that the message contains the correct pseudorandom number, and both the client and server synchronously advance their generators. Any client message that is either repeated or blocked will be detected by the server. Currently, when the server detects such a mismatch, it simply writes the name of the offender to its log file.

One way the system discourages snooping is by limiting the amount of game information present on the client. The world is divided into rooms, and each client knows only which objects are present in the same room as the player, as well as the positions and names of these objects. The client also has knowledge of the entire map of the room, and the names of all players who are logged in. Even armed with all of the game data present in the client, a player would not have much of an advantage. All object data is stored on the server, and only reaches the client through a restrictive set of messages.

Using the administrator mode, it is possible to gain complete control over a server. The client only accepts administrator mode commands when the server grants it permission; however, it would be possible for an attacker to modify the client to get it to display administrator mode. For this reason, the server verifies each incoming administrator command, to make sure that its associated account actually has administrator privileges. Using administrator mode thus requires knowledge of an administrator account's password, or physical access to the server machines.

There are no known security holes in the current scheme. In order to cheat, a player would have to reverse the MD5 algorithm, discover the password to the Crusher encryption scheme or break the scheme, discover and reproduce the random packet state algorithm, or modify the client executable. Even by modifying the client executable, it is only possible to discover a relatively small amount of information about the player's local area.

Chapter 3

The Blakod language

Blakod is the language that BlakSton uses to define objects in its game world. BlakSton contains a byte compiler from Blakod to an simple intermediate language, and an interpreter for the intermediate language. This chater informally describes the syntax and semantics of Blakod.

Blakod is an object-oriented language that uses message passing as a primary means of flow control. An object consists of some private data, called *properties*, and a set of methods (which we refer to as *message handlers*) for observing and manipulating this private data. The syntax of the language is much like that of C or Pascal.

Because Blakod is a special-purpose language, meant to describe objects for use in role-playing games, there is a close relationship between the Blakod written for a game and the runtime system in the BlakSton server. Blakod code calls built-in C functions in the server when an operation would be too slow or complicated in Blakod, or where the operation requires communication with other parts of the server, such as sending messages to clients running on user machines.

3.1 Specification

A Blakod code file contains definitions for one or more classes. Each class definition consists of six parts, as illustrated in figure **??**. The class header lists the name of the class, and optionally the name of a single superclass. Only single inheritance is allowed.

The constant block lists identifiers to be used as abbreviations for simple constant expressions. Such an identifier evaluates to the right hand side of the assignment given in the constant block wherever it appears. The constant block can also contain `include` compiler directives that can be used to include a set of constant definitions from other files.

Identifiers in the resource block reference filenames and strings. A class's resources are placed in a resource file during compilation, and this file is sent to clients. Each resource is assigned a unique number during compilation, and it is these numbers that the server uses to refer to files and strings in messages to the client. In Blakod, resources can only be passed as parameters or appear by themselves on the right hand side of assignments; they cannot be assigned to or appear in compound expressions.

Properties are the equivalent of protected class data in C++. A class inherits all the

```
Classname is Superclass                     % Class header

constants:                                  % Constant block

  include constants.khd
  seconds_per_hour = 3600

resources:                                  % Resource block

  filename = picture.bmp
  string = "Text goes here"

classvars:                                  % Class variable block

  ciBitmap = filename

properties:                                 % Property block

  piWeight = 10

messages:                                   % Message block

  Move(distance = 1, direction = 1)
  "This message handler moves this object in some way."
  "And these comments can extend over multiple lines."
  {
    local i, j;
    ...
  }

end
```

Figure 3.1: Basic format of a Blakod class

properties of its direct and indirect superclasses; these properties are all accessible within the class. Properties of a superclass can appear in the subclass's property section in order to override the superclass's values for these properties.

A class variable is a piece of read-only, per-class data. Class variables are inherited by subclasses just as properties are. The main use of class variables is to save space in the object database; data that doesn't vary across instances of a class should be put in class variables to avoid allocating space in each object for the data.

A subclass can overload a superclass's class variable by declaring a property with the same name. The subclass can then use the property as read-write data just like any other property. In this way, a class high in the hierarchy can declare read-only data to save space in most objects, while subclasses can still write to the location if they need to (though instances of the subclass will of course require extra space to hold the property).

Properties and class variables can be initialized to any constant expression. If no expression is given, they are initialized to the special value nil.

The message block contains the class's message handlers. Each message handler begins with a header that lists the handler's name and parameters. Parameters are matched by name, so that calls of a handler need not assign values to all of the parameters listed in the handler's header. The header can list default values for any of its parameters; a default value is bound to its parameter when a call does not list the parameter. The header is optionally followed by a comment, describing the message handler. Administrators can view these comments in the game.

A message handler's body contains a sequence of statements, each ending with a semicolon. The first statement optionally declares a list of local variables used by the handler. A class also inherits its superclass's message handlers. When an object's class hierarchy contains more than one message handler of the same name, the handler for the lowest class in the object's hierarchy is called first. This handler can propagate the message to the next handler up the hierarchy, or it can return a value, in which case the other handlers are not called.

A special message handler called `Constructor` is called when an object is created. Right before an object's constructor is invoked, its default property values are set in descending class order, starting with the top of the object's class hierarchy and ending with the object's actual class. This is the reverse order of the message handler call sequence, allowing subclasses to override property values of superclasses.

Some objects call the message `Constructed` in their constructor. This is no longer needed, but at one time was done to allow certain processing after the `Constructor` message was propagated all the way up to the `Object` class. Since `Object`'s constructor now does very little, `Constructed` is no longer necessary.

Class and message handler names have global scope. Each class name must be globally unique, and message handler names must be unique within a class. The scope of all identifiers appearing on the left hand sides of assignments in the constant, resource, property, and classvar blocks is the class in which the blocks appear. Parameter names and local variables appearing in a message handler have scope restricted to that message handler.

3.1.1 Statements and expressions

Blakod statements correspond roughly to similar statements in C. The main differences are due to Blakod's dynamic type scheme, and message handler calls.

Values in Blakod are 32 bits long; 4 of these bits act as a tag that determine the value's type. Thus, 28 bits are actually available to the program[1]. Blakod can directly express values of type integer, resource, class, message handler, and nil. There is no non-integer numerical type. The interpreter uses other tag values for runtime types such as objects and list cells. Type checking is done at runtime; thus, expressions with type errors will compile but may cause runtime errors.

The special value nil is denoted by a dollar sign (`$`). Nil is assigned to message handler parameters that are not explicitly assigned a value, and it is also used to mark the end of a list. Nil can be assigned to variables, returned from message handlers, or tested for equality; it is an error to perform any other operation on nil.

The special value `self` contains the identifier of the object whose message handler is being executed. `Self` is implemented as a property of every object.

Expressions consist of identifiers, constants, and message handler calls combined with standard operators. Blakod contains the following operators: addition, subtraction, multiplication, division, unary minus, modulo, logical and bitwise AND, OR, and NOT, and the standard relational operators (equal, less than, etc.). A boolean expression evaluates to 0 if it is false, or nonzero if it is true. The logical AND and OR operators "short-circuit;" i.e. they only evaluate their second arguments if necessary. The following table shows the precedence of Blakod operators in descending order.

− NOT ∼
∗ / MOD
+−
< > <= >= = <>
&
|
AND
OR

Blakod programs are made up of assignment statements, conditional clauses, loops, calls, and return statements. Comments are introduced by the percent character (`%`) and extend to the end of the line.

Assignments take the form *lvalue* `=` *expression*, where *lvalue* is the name of a property or a local variable. The right hand side is evaulated, and the result is assigned to the left hand side.

The `if` statement performs conditional execution. Its syntax is

`if` *test* { *then-clause* } or
`if` *test* { *then-clause* } `else` { *else-clause* }.

[1] With one sign bit, this means that $2^{27} - 1 \approx 134$ million is the largest number expressible in a single Blakod variable.

The braces are required in all cases.

The basic looping construct in Blakod is the `while` loop. A while statement has the syntax

`while` *loop-test* { *loop-body* }.

The loop body is evaluated until the loop test becomes false (equal to zero). The `for` loop construct is for use with lists only. Its syntax is

`for` *loop-var* `in` *list* { *loop-body* }.

The loop variable takes on each of the first values of the list during evaluation of the body of the loop. The `break` and `continue` statements can be used to interrupt loop execution as in C. These statements apply to the innermost enclosing loop; it is an error for these statements to appear outside a loop.

Function calls may appear either as expressions, in which case they evaluate to the return value of the function they call, or as statements, in which case the return value is ignored. The most important call is `Send`, which calls an object's message handler. The syntax is

`Send(` *object,* `@`*message*, `#`*param1* `=` *val1*, `#`*param2* `=` *val2*, ... `)`

Object gives the object whose message handler is to be called; *message* is the name of the message handler to call. The parameters are matched by name, so they can appear in any order. Execution immediately passes to the object's message handler, and returns to the caller when a return statement is reached in the handler. All parameters do not need to be supplied. Any parameters not passed to a message handler are initialized to the value specified in the message handler definition before the message handler code gets control.

`Post` has the same syntax as `Send`, but the call is not made until after the current message (and all of the callers, back to the original client message forwarded by the server) is complete. This is useful when something should be done after the current call, such as responding to speech said by a user.

There are two kinds of return statements, `return` and `propagate`. One of these must be the last statement in every message handler. A `propagate` statement indicates that execution should proceed to the message handler of the same name in the closest superclass in the current class's hierarchy, if any. A `return` statement indicates that execution should return immediately to the caller. `Return` can optionally be followed by an expression whose value is returned to the caller as the value of the calling expression. If no expression appears after the `return`, the value nil is returned to the caller.

Debug strungs are a special kind of string that is only intended for debugging use. They are specified by a text string inside double quotes in an expression. The primary use for debug strings is to pass them to the `Debug` function, described in the next section, for output to a log file. However, they can also be used as parameters to `StringEqual` and `ParseString` for use in text comparisions and in parsing mail destination lists. Debug strings are not handled by the other string functions, so care must be taken not to use debug strings where they are not appropriate.

3.1.2 Built-in functions

Below we give brief descriptions of each built-in function, arranged by category. All parameters are passed by value. A more thorough description is given in the previous chapter.

List operations

These functions support linked lists similar to those in Lisp. The interpreter has a linked list data type; values of this type are passed as list arguments to these functions, and appear in `for` statements.

`Cons(` *expr1, expr2* `)`
`First(` *list node* `)`
`Rest(` *list node* `)`

Same as their Lisp counterparts. `Cons` creates a "dotted pair" of its arguments, which we refer to as a *list node*. `First` and `Rest` return the first and second parts of a list node.

`List(` *expr1, expr2, ...* `)`

Create a list of its arguments. A list is a sequence of list nodes, where the first element of the n^{th} node contains the value of the n^{th} expression, and the second element contains a reference to the $(n+1)^{st}$ node. The second element of the last node contains nil.

A call to `List` can be abbreviated by the syntactic sugar `[` *expr1, expr2, ...*`]`.

`Nth(` *list, n* `)`

Return the first element of the n^{th} node in the list.

`SetFirst(` *list* `)`
`SetNth(` *list, n* `)`

Mutate the first element of the n^{th} node of *list* in place, that is, without creating any new list nodes. SetFirst is a special case with $n = 1$.

`Length(` *list* `)`

Return the length of the given list.

`DelListElem(` *list, n* `)`

Returns the list with the first occurrence of the specified value (n) removed from the list.

Communication

These commands assemble and send messages that the interpreter passes to the client.

`AddPacket(` *expr1, expr2, . . .* `)`

Add to the interpreter's communication queue. The first argument gives the length of the second argument in bytes, the third argument gives the length of the fourth argument, etc. The communication queue contains everything passed in via calls to `AddPacket` since the last call to `SendPacket`.

`SendPacket(` *session* `)`
`SendCopyPacket(` *session* `)`
`ClearPacket( )`

Send the contents of the communication queue to the client identified by *session*, and then clear the queue. The interpreter passes session numbers to Blakod when users log on.

`SendCopyPacket` performs the same function, except that it doesn't clear the queue. The queue can be cleared manually by calling `ClearPacket`.

Class operations

`Create(` `&`*class,* `#`*param1* `=` *val1,* `#`*param2* `=` *val2, . . .* `)`

Create and return a new object of the given class. The parameters are passed to the class's constructor.

`IsClass(` *object,* `&`*class* `)`

Return true if the object is a subclass of the given class.

`GetClass(` *object* `)`

Return the class of the given object.

Strings

`StringEqual(` *string1, string2* `)`

Return true if the two strings contain the same ASCII string; the comparison is case insensitive.

`StringContain(` *string1, string2* `)`

Return true if the string1 contains the ASCII string in string2; the comparison is case insensitive.

`SetString(` *string1, text* `)`

Set the string to the given ASCII text.

`SetResource(` *resource, string* `)`

Set the dynamic resource to the given string.

`CreateString( )`

Create a new, empty string.

`ParseString(` *string, separators, message* `)`

Parse the given string into a set of substrings, separated by characters in the string `separators`.

Timers

`CreateTimer(` *time, message* `)`

Create and return a new timer. The timer will go off in `time` milliseconds, when the given message will be sent to the current object.

`DeleteTimer(` *timer* `)`

Delete the given timer.

`GetTimeRemaining(` *timer* `)`

Return the number of milliseconds remaining on the given timer.

`GetTime( )`

Return the current wall clock time.

Room operations

`LoadRoom(` *expr* `)`

Return a reference to the room description given by the resource number *expr*. This function is used to load the room's description file when the room is created. The data that BlakServ loads about a room is nearly permanently stored in memory. It is only unloaded upon a `reload sys` command, which unloads the data about every loaded room. The Blakod for every game must reload rooms after every system reload, and also erase all references to the room data that no longer exists. I coded Meridian 59 to automatically take care of this through the `Room` class, and it is important not to remove that code. Other games may not need rooms at all, and can ignore this warning. There is no way to unload room data except by a system reload.

`CanMoveInRoom(` *room, row1, col1, row2, col2* `)`

Return true if room does not contain any impassable walls when moving from (*row1, col1*) to (*row2, col2*). This is used to determine if monster moves should be allowed. This is currently the only interaction between Blakod and the geometry of a room.

Hash tables

`CreateTable( )`

Return a new, empty hash table. The "size" of the table is fixed in `ccode.c`, but the hash table uses open hashing. Open hashing is a very common hashing system which is quite simple. Each entry in a hash table is actually a linked list of elements that have the same hash value. In this way, the hash table is never full, because it is not of a fixed size, just a fixed number of hash values. This considerably eases coding using a hash table because the programmer never has to deal with a full hash table. However, implementing open hashing is slightly more complex. I believe that the hash tables work perfectly in BlakServ.

`AddTableEntry(` *table, key, value* `)`

Add the (key, value) pair to the given hash table.

`GetTableEntry(` *table, key* `)`

Return the value matching the given key in the hash table, or nil if the key is not present in the table.

`DeleteTableEntry(` *table, key* `)`

Remove the entry in the hash table with the given key, if any.

`DeleteTable(` *table* `)`

Free all memory associated with the given hash table, and delete the table.

Miscellaneous

`Random(` *expr1, expr2* `)`

Return a random number uniformly distributed over the given closed interval of integers.

`Debug(` *expr1, expr2, ...* `)`

Print given values on the server's terminal.

`Bound(` *expr1, expr2, expr3* `)`

Bound *expr1* to the interval [*expr2, expr3*], and return the result.

`Abs(` *expr* `)`

Return the absolute value of the given expression.

`GetInactiveTime(` *session* `)`

Return the number of milliseconds since a message was received on the given session.

`IsList(` *object* `)`

Return true if the object is a list node.

3.2 Intermediate language

Blakod is byte-compiled into an intermediate language we call Bkod. Bkod is an extremely simple language, similar to a generic register-oriented assembly language. Each instruction contains an opcode, one to three sources or destinations, and occasionally some other fields. For a full specification, see Appendix **??**.

Bkod contains opcodes for unary and binary operations, jumps, function calls, and returns. The unary and binary operations have the same semantics as C (except, of course, that they operate on Blakod's 28 bit values). Jumps may be conditional or unconditional, and returns may or may not propagate (corresponding to the Blakod commands `propagate` and `return`).

The only locations allowed in Bkod instructions are local variables and properties. Temporary values, such as values that arise in the evaluation of complex expressions, are stored in extra local variables generated by the compiler. Immediate (constant) values can also appear in Bkod instructions.

In addition to instructions, a `bof` file contains some organizational information about the class from which it was compiled. The class has a table of message handlers; each handler contains a list of its parameters, as well as the actual handler's Bkod instructions. The file also contains a mapping of `bof` file offsets to source (Blakod) line numbers; the server uses this to report Blakod line numbers in debugging messages.

3.3 Existent Blakod

3.3.1 Class Hierarchy

As of the date of this writing, the following class tree shows the class hierarchy of the Blakod, except for the leaves. In most cases leaf classes have little or no added functionality. Their only purpose is to have resources for the individual object and use these to override properties.

```
Object*
    ActiveObject*
        Holder*
            NoMoveOn*
                Battler*
                    Monster*
                        Council
                        Factions
                        Mummy
                        Temples
                        Towns
                            BarloqueTown
                            CorNothTown
                            HazarTown
                            JasperTown
                            MarionTown
                            TosTown
                    Player
                        User
                            dm
                                admin
            Room*
                Guest1
                Guest2
                Guest3
                Guest4
                Guest5
                Guest7
                GuildHall
                MonsterRoom
                    FeyForest
                    Guest6
```

```
                ObjectRoom
    Item*
        ActiveItem*
        PassiveItem*
            AttackModifier
            DefenseModifier
                Armor
                Helmet
                Pants
                Shield
            ForgetPotion
            Healer
            MiniGame
            Necklace
            NumberItem
                Ammo
                Food
            Ring
            Token
            Wand
            Weapon
                RangedWeapon
    PassiveObject*
        Brain*
        GuildCommand
        ManaNode
        News
        Sickness
            Disease
        Skill
            Proficiency
            Stroke
                Unarmed
        Spell
            AttackSpell
            DMSpell
            TouchAttackSpell
        TreasureType
UtilityFunctions*
    System* (an important leaf class)
```

* infrastructure class

Non-leaf classes in the class hierarchy

3.3.2 Some important classes

3.3.3 Holder

The **Holder** class is critical to the function of the system in many ways. See the following table for its properties.

Property name	Description
`plActive`	A list of active objects being held by this object.
`plPassive`	A list of passive objects being held by this object.
`piBulk_hold`	The amount of bulk this object is currently holding.
`piWeight_hold`	The amount of weight this object is currently holding.

The **Holder** class uses the concept of active and passive objects. When an **Holder** class receives a message indicating something has happened or might happen, it sends this message to all the active objects that it holds. This is the primary way that objects learn about what is going on with other objects, and how they affect other objects.

Many of the messages come in pairs. This is because an object first checks to see if it can do something (such as cast a spell), and then if nothing prevents it, it actually performs the action. The most important of these messages are summarized in the following table.

Message name	Description
ReqSomethingUse	An object would like to use an item.
SomethingUse	An object just used an item.
ReqSomethingMoved	An object would like to move.
SomethingMoved	An object actually did move.
ReqSpellCast	An object would like to cast a spell.
SpellCast	An object just cast a spell.
SomethingChanged	An object just changed its look (either bitmap or overlays).
⋮	⋮

The idea here is that rooms have no owner, but every other object is either directly owned by a room or owned by an object which is owned by a room, some levels up. When something happens in a room, every active object in the room is sent a message, and any of these objects which are holders forward the message to any active objects they are holding.

Room

The **Room** class derives from the **Holder** class, but adds essential features to store object coordinates and a few other things. Its properties are listed in the following table.

Property name	Description
piRoom_flags	Specified properties of a room—whether it is a no combat zone, whether it is an anti-magic zone, etc.
prRoom	The resource of the room filename (.roo file)
prmRoom	The server room id returned by the server when the .roo file is loaded each time the server is started (or reloaded).
piRoom_num	The room id for this room, which is unique for each room (constants have prefix RID_)
piSecurity	The security value of the .roo file associated with this room, retrieved from the server.
prMusic	The resource of the midi file to play for users in this room.
piNorth	The room id of the room to send objects to if they leave to the north.
piSouth	The room id of the room to send objects to if they leave to the south.
piEast	The room id of the room to send objects to if they leave to the east.
piWest	The room id of the room to send objects to if they leave to the west.
piBaseLight	The base light level in this room (constants have prefix LIGHT_).
piOutside_factor	How much this room's light is affected by time of day (constants have prefix OUTDOORS_).
piDirectional_percent	How effective directional light is in this room.
piDirectional_light	An internal measure of directional light calculated over time.
prBackground	The resource of the background bitmap of this room.
piDispose_delay	The amount of time between sending DestroyDisposable() messages.
ptDispose	The timer id returned by the server when a timer is created to call DestroyDisposable().
plExits	The list of exits from this room (accessed by a user hitting the space bar).
plSector_changes	The list of all sectors that have a changed floor or ceiling height from the .roo file height.
plWall_changes	The list of wall ids that have a different animation type from the .roo file value.
plTexture_changes	The list of wall texture ids that have been assigned a different texture from the .roo file value.
plSector_light_changes	The list of sectors that have a different light value from the .roo file value.
plEnchantments	The list of all room enchantments that are currently affecting this room.

Property name	Description
pbUser_in_room	Internally calculated. True when there is at least one user in the room.
plPeriodic_sounds	The list of all sounds that are set to periodically be sent to all users in the room.
piPeriodic_sounds	The number of milliseconds between periodic sounds going off.
ptPeriodic_sounds	The timer that goes off when a new periodic sound is set to be sent to all users in the room.

An object of class **Room** stores the angle, row, column, fine row, and fine column of each object it is holding in the plActive and plPassive lists, besides the actual object.

The **Room** class keeps track of when the first user enters the room and when the last user leaves. The room itself uses this to send all the objects in the room a DestroyDisposable() when the user leaves, or every piDispose_Delay seconds when users are present. Objects which are not permanent should delete themselves upon receiving this message. Items by default do this, as do monsters. Any "permanent" items or monsters override this behavior.

Monsters

The **Monster** class has a simple system of fighting, by returning attacks by anything that attacks a monster, and retaliating by a timer. It has properties to keep track of its hit points and damage capabilities, and to create treasure when it is killed.

This class was originally written by Chris Kirmse, but was rewritten by John Murphy; he and Damion Schubert understand its behavior best.

3.3.4 Users

The code and data to handle users is split primarily into two classes, **Player** and **User** (which derives from **Player**). The **Player** class handles attacking, using and holding items, and animations and overlays. The **User** class handles all the interaction with the server (which comes through the message handler ReceiveClient()).

Using items

The **Player** class allows users to use items. Items may be used in several different ways, as seen in table **??**.

Table **??**

Value of item's piUse_type	Description
ITEM_CANT_USE	The item cannot be used.
ITEM_SINGLE_USE	The item does something when used, like a magical staff or bandage.
ITEM_USE_HAND	The item is held in a hand.
ITEM_USE_BODY	The item is held on the body.
ITEM_BROKEN	The item is broken, and so cannot be used.

Each user has an amount of *space* to hold things in his hands or on his body, stored in `piHand_space` and `piBody_space`. If the amount of space is greater than the amount the item will use (specified in its `piUse_amount`), then there is enough space to use the item.

Items themselves may have other restrictions on usage–for example, only one weapon may be used at a time, and if a user tries to use another weapon, the currently used weapon will "unuse" itself.

3.4 Strings and dynamic resources

3.4.1 How player names work

Player names presented quite a challenge to us early on in BlakSton, but after several tries we came up with a good solution. The problem is that Blakod refers to all object's names as resources. This makes it possible for a piece of Blakod to deal with all objects the same–there is no special case code for users. However, players need the ability to change their name (when they create their character the first time, and any time they commit suicide). Additionally, player names are not known before the game is shipped, which is the case for all other resources.

The solution currently implemented in BlakSton is that player names are treated as special resources, called *dynamic resources*. All resources with resource ids of at least 1 million are treated as dynamic resources. Unlike regular resources, when the server saves the game state, it also saves all of the dynamic resources. A C code function (`SetResource`) exists for the Blakod to change a player's name. The only remaining issue is how to make sure all clients always know the dynamic resources associated with every player currently logged in.

This is simple to accomplish–when a player logs in, all other players are sent a special message from the server with the new player's name resource id and the string value of the resource. The new player is sent a message with every logged in player's resource ids and associated strings. In this way, all clients always know the string values of all static resource ids and all dynamic resource ids of currently logged in players.

3.4.2 How strings and dynamic resources are saved

When the server saves the game state, it writes several files with a suffix indicating the time of the save. One of these files is called `dynarscs.X`, which contains the dynamic resources in the same format as a `.rsc` file. When the game is reloaded, the server reads the file and so never loses track of player names.

The game strings are saved to a file called `striings.X`, which is in a very simple binary format. It starts with the bytes 00, 00, 00, 01. Then the number of strings is written as a four byte integer in little endian format. Then each string is written to the file, as a two byte integer length and then the actual string data.

Chapter 4

Tools

This chapter describes the parts of the system other than the server and the client. This is mainly a guide to using these standalone programs, since their design is for the most part trivial. However, in the discussion of the Blakod compiler, we touch on some of the implementation issues of Blakod that are separate from the specification of the language. In the section on the room editor, we also explain some of the structures that are used in the client's graphics engine to describe a scene.

4.1 Blakod compiler (`bc`)

The Blakod compiler is a command line program that byte-compiles a Blakod source (`kod` file) into an object file (`bof` file), and usually a resource file (`rsc` file). The Blakod interpreter in the server loads all `bof` files at startup, while the `rsc` files are sent to clients.

Link errors are appended to a file called kodbase.txt with a lowercase letter and an identifier to indicate unresolved linkages. The lowercase letter indicates the type of the identifier that was unresolved (property, class, message handler, or class variable). This results in "unrecognized character in kodbase.txt" messages in the server status window if this kodbase.txt file is loaded. To resolve these messages, the link error in Blakod must not only be corrected, but the error message at the end of kodbase.txt must be manually deleted. The compiler will not remove these error messages, even after the link error is resolved.

4.1.1 Design of the compiler

The Blakod compiler follows traditional compiler design, with separate components for lexing, parsing, code generation, and optimization. It links with the `flex` and `bison` programs, which are GNU versions of the UNIX utilities `lex` and `yacc`. These utilities take as input simple descriptions of Blakod's tokens and grammar, and produce as output the parser component of the compiler.

The parser checks the input Blakod source for errors, and converts it to an internal representation. At the top level, this representation consists of a list of the classes present in the source file. Each class holds a list of component resources, class variables, properties, and message handlers. Finally, each message handler contains a parameter list, information on its local variables, and a list of statements. Expressions within statements are represented as standard inorder expression trees, with operators at the nodes and values at the leaves.

As the parser encounters new identifiers, it inserts them into a global symbol table. This provides a rudimentary type checking, preventing, for example, a local variable and a parameter to share the same name. The symbol table records the string name of each identifier, as well as a number that the object file will use to refer to the identifier. The parser adds the names of built-in Blakod functions to the symbol during initialization; these use well-known identification numbers so that the server can tell which built-in function is being called by a particular statement.

If the parser encounters errors, these are reported and compilation stops. If there are no errors, the code generator recursively traverses the code tree and produces `bof` intermediate language statements for each Blakod statements, and writes these out to disk. Finally, the resources for all the classes present in the input source file are placed in a `rsc` file and encrypted. Encryption is necessary to keep users from reading strings which might give them an advantage in game play. If no resources are present, the `rsc` file is not generated.

The compiler performs the single optimization of constant folding; that is, constant expressions are replaced by the resultant value of the expression. This optimization is important because it improves code readability: bitwise constant combinations and complicated formulas can be expressed simply without impacting performance. Upon reaching an expression, the code generator calls the optimizer to simplify the expression if possible; the simplified expression replaces the original form.

Because there is no linker, references to identifiers in other classes must be stored externally. A text file named `kodbase.txt` keeps track of all identifiers in previously compiled classes. Each line in `kodbase.txt` contains an identifier's text string, the identifier's compiler-generated number that appears in object files, and a letter indicating the identifier's type—either class, message handler, class variable, resource, property, parameter, or the special value "missing." The missing value is for forward references, that is, identifiers that the compiler encounters before it can determine type information. The compiler will replace the missing value with the identifier's type when it can be determined from another source file.

The compiler loads `kodbase.txt` upon startup, and writes it out again after code generation. In addition to substituting for a linker, the file is used by the server in two ways. First, saved games reference identifier names, so that a saved game can be reloaded even if all identifier numbers change. Second, identifier names are used in administrator mode for user convenience.

Saved games can be reloaded even if all identifier numbers change, since saved games reference the names, not the numbers. Rebuilding the Blakod with working off the same kodbase.txt and hence the same reference numbers will still allow the server to reload saved games. To rebuild all the Blakod, you should first delete all the compiled bof files.

The compiler supports an `include` directive that inserts one source file in another. Though this directive may appear anywhere, it is typically used to include global constants in the `constants` section of a class declaration. `include`s may be nested to a depth of 10.

4.1.2 Running the compiler

The compiler is a console mode Win32 program named `bc.exe`. Its simplest invocation is

`bc` *input_filename*`.kod`

which compiles the input file to output files with `.bof` and `.rsc` extensions. The command line switches are

-d	include debugging information in the `bof` file (see the description of the `bof` file format in Appendix ??).
-K filename	use *filename* as the kodbase file.
-I path	look for included files in the *path* directory.

If compilation completes without errors, the compiler exits with the value 0; otherwise, it exits with a nonzero value. The build system uses this return value to know when to terminate.

In `bof` files, properties are identified by number. The `kodbase.txt` file is the only place that a subclass can find the number of properties in its superclasses; therefore, when a class is compiled, all of its subclasses must also be recompiled, in case a property has been added or deleted. This is why the build system (see section ??) builds Blakod from the root of the hierarchy down to the leaves, and why subclasses are made to depend on their ancestors.

4.2 Room editor

The room editor reads, edits, and saves `.roo` files. The editor is a modified version of WinDEU, a Win32 GUI program for editing DOOM data files. Because it uses Borland's Object Windows Library (OWL), it must be compiled with Borland's C++ compiler.

A help file distributed with the editor describes the mechanics of editing parts of a room file. Below we detail the differences between WinDEU and the Blakston room editor.

An initialization file called `windeu.ini` specifies options for the WinDEU. The two options that we added to WinDEU are `bitmapdir`, which specifies the directory containing the compiled textures (`.bgf` files), and `bitmapspec`, which gives the filespec for the texture files. This should always be set to `grd*.bgf`, because the client assumes that texture graphics have filenames of this form.

If a file is given on the command line to the editor, that file is loaded upon startup. Otherwise, the editor starts up without a room file, in a mode that used to contain many options in WinDEU, but is now obsolete. The only options available are loading a room file to edit, or viewing a list of all available textures. When a texture is viewed, its string name (specified by the *-n* option to `makebgf`) is also shown.

When the editor saves a file, it first renames any existing file with the same name by appending a tilde the end of the filename. This provides a simple backup mechanism, and also protects users in the case of a bug in the editor that causes it to crash during a save.

4.2.1 Basic concepts

As in DOOM, the basic elements of a room file are *linedefs*, *sidedefs*, and *sectors*. A linedef is a line on the map, connecting one point to another. A sidedef is a description of the textures on one side of a wall; a linedef may have up to two associated sidedefs, one for each side of the wall. A sector is a polygonal region on the floor, which conceptually also maps to the same polygon on the ceiling. Properties of a sector include the associated wall and floor textures, as well as a number of flags that are described below.

In order to save space, sidedefs that are exactly equivalent are merged when the room is saved to disk. In other words, if two linedefs reference two identical sidedefs, the linedefs are modified to reference one of the sidedefs, and the other is discarded. When the room is later reloaded into the editor, this procedure is undone by assigning each linedef two unique sidedefs. Thus, the merging procedure does not destroy any information.

A sidedef references up to three textures, referred to as *normal*, *above*, and *below*. To understand how these are placed, consider two adjacent areas with different floor and ceiling heights. The below texture is drawn in the vertical space between the two floors (like a riser on a staircase). Similarly, the upper texture is drawn between the two ceilings. The normal texture is drawn between the higher of the two floors and the lower of the two ceilings. Each of these three textures may be set independently in each sidedef.

4.2.2 Graphic engine settings

Because the graphics engine in the client differs significantly from the DOOM graphics engine, many of the original WinDEU settings were removed or replaced. In particular, the "Things" mode of the editor was mostly removed—it was used to place monsters in DOOM, while in Blakston, these are set in Blakod. Below we outline the other differences.

Coordinates

The room editor displays vertex coordinates that don't exactly correspond to internal coordinates in the client or Blakod. While the units are the same in the editor and Blakod, those in the client are 64 times smaller. In the editor, positive y is towards north, while in Blakod and the client, positive y is toward the south. The editor displays all three sets of coordinates in real time as the mouse moves around the screen.

To restate, the editor displays both its internal coordinates for vertices, and the equivalent coordinates that Blakod will use. Thus, there is no need to ever use the internal editor coordinates, unless that is helpful to room designers. These coordinates are displayed for reference only; they aren't even saved in the room file.

In the editor, the origin is at an arbitrary point. In Blakod and the client, the origin is at a user-specified point, or at the upper leftmost vertex in the room if no point is specified. The user specifies the origin by placing a point on the map in the editor's Thing mode. A similar point can be placed to indicate the lower right corner of the room. This is useful for placing linedefs outside the area where players can move, creating the illusion that rooms are smoothly connected. The room Blakod can also automatically move a player from one room to another when the player moves outside the rectangle given by the two points in Thing mode.

Texture alignment

Texture alignment is achieved by specifying x and y offsets into the textures in a sidedef or sector. Since only one pair of offsets exists in each sidedef or sector, the lower, upper, and normal textures on a linedef all use the same offsets, and the floor and ceiling textures in a sector also use the same offsets. Thus, it is not always possible to align every texture to look smooth in the client.

A question in texture alignment is where the origin of a texture is placed on a wall—the natural choices are at the northwest corner (drawing “top-down”), or at the southwest corner (drawing “bottom up”). By default, above textures are drawn top down, while normal and below textures are drawn bottom up. This arrangement tends to require fewer adjustments by the user to align textures; however, these defaults can be overridden by flags in each sidedef.

Some functions in the editor perform automatic alignment of sidedef textures. These functions carry carried over from WinDEU.

Lighting

Each sector may have its light level set independently. Sidedefs that border on the sector are drawn with the same light level as the sector itself. The actual brightness of a sector when drawn in the client is a combination of several factors: the lighting level set in the editor, ambient light, proximity of the viewer, and any special effects.

The light level in a sector may be set to any value between 0 and 255. Additionally, the sector contains a flag that can be set to make it immune to the effects of ambient light. This is useful for indoor areas, where the time of day and sun’s position should not change the lighting level of the sector. However, since the ambient lighting flag and the light level information occupy the same byte in the `.roo` file, one bit of resolution in the light level is discarded. Thus, setting the low bit of the light level in a sector has no effect; the light level is always a multiple of two.

A sector can also be set to have its light level flicker randomly. When the flicker flag is set, the client randomly sets the light level of the sector every 100 milliseconds. The light level is chosen uniformly between the sector’s given light level, and the maximum possible brightness.

Additional fields

There are a number of additional fields in each sidedef and sector that are not present in WinDEU. We describe each briefly below.

By default, the client only draws a wall on the map after the player has seen it. Two flags in the room editor can make the wall either always appear on the map, or never appear on the map, regardless of whether the player has seen it.

A flag in a sidedef can cause all textures on the sidedef to be right-left flipped. This helps keep down the number of textures in a game; a pair of symmetrical textures can be combined into one.

Transparent textures present several problems. For one thing, they are rather inefficient, since the client’s graphics engine must also draw whatever is behind a transparent wall. In many places, we want the benefit of transparency to give the top of a texture a rounded appearance (such as the canopy of a forest), and we can guarantee that nothing behind the wall need be drawn, because of the layout of the room. In these situations, the "no look through" flag should be set on the sidedef; the sidedef will be drawn transparently, but the engine won't draw anything behind it, improving performance. Another problem with a forest canopy is that textures tile vertically by default—clearly this isn't desired behavior for trees, signs, and other places where a linedef is used to represent objects other than walls. For these cases, the editor has a "no vertical tile" flag that can be set for each sidedef.

Each sector has a depth field that can be set to any of four values (one of which is zero depth, the default). Objects in sectors with non-zero depths are drawn extending into the ground, as if they are wading through a liquid. We use this effect for water and lava.

Two types of texture animation are available in the room editor. In the first, the bitmap displayed on a wall or sector changes at a regular interval between different bitmaps. The length of the interval can be set in the editor in the "animation speed" field of a sidedef or sector. If this is zero, there is no animation; if it is nonzero, the texture animates through all groups present in the `bgf` file of the texture (see the description of groups in section **??**). Another animation is a smooth scrolling of a single bitmap in one of the eight cardinal directions. The speed of the scrolling can be set to one of four possible values (with zero speed being the default). These two animation types may not both be specified for a given sidedef or sector.

Another field in every sidedef and sector allows the user to specify an arbitrary two-byte tag. While specifying this tag itself has no effect, all client/server protocol messages that refer to parts of a room do so via this tag value. This extra level of indirection allows a single protocol message to refer to many sidedefs or sectors simultaneously, reducing the number of protocol messages that need to be sent. In addition, all sectors with the same tag value and same light level flicker in unison. We found this useful in some room designs where we needed neighboring sectors to flicker together.

4.3 Bitmap complier (`makebgf`)

The client loads special-purpose graphic files with a `.bgf` extension. The `makebgf` program takes as input one or more standard Windows bitmaps and a list of options on its command line, and produces as output a single `.bgf` file. The `.bgf` file organizes bitmaps in a way that is convenient for the client to reference, and also stores some information that helps in animation.

Since all graphics in the game use a single palette, the palette information in Windows bitmaps is redundant, and doesn't appear in a `.bgf` file. The `.bgf` file is also compressed to save disk space on users' machines.

4.3.1 Running `makebgf`

`makebgf` is a Win32 console mode program, run from the command line. The command line switches operate as follows.

First, specify the output file with the *-o* switch. The *-s* switch optionally specifies a "shrink factor" that's used to determine the display size of the bitmap. For example, the player bitmap is 128 by 256 pixels, but it's built with *-s 4*, so it's displayed as if it were 32 by 64. Extra resolution in the bitmap is displayed when the object is close. The default is shrink factor 1.

The *-n* switch allows you to insert a 32 byte string into the bgf file; this is displayed by the room editor as the name of the texture.

The *-r* switch causes all the bitmaps in a bgf to have their rows and columns swapped (i.e. a 90 degree rotation). This is used for wall textures, which the client draws rotated 90 degrees for better performance.

Next you give the number of bitmaps in the file, followed by their filenames. Wildcards are allowed.

Last you specify how the bitmaps are arranged into groups. Each group consists of the object viewed from different angles. First you give the number of groups. Then, for each group, you give the number of bitmaps in the group, followed by the index into the filename list of each bitmap (the first bitmap is numbered 1). For example:

```
makebgf -o out.bgf 4 a b c d 2 1 1 3 2 3 4
```

This makes a bgf with 4 bitmaps and 2 groups. The first group has bitmap *a*, which is visible from all 360 degrees. The secound group has three bitmaps, each visible through an angle of 120 degrees. The *b* bitmap is the face on view, and the others progress around the circle in increasing order; that is, the *c* bitmap is visible from 120 degrees, and the *d* bitmap from 240 degrees.

Specifying index 0 means that no bitmap should be displayed for combination of group and angle. This is useful for overlay bitmaps, where, for example, parts of a face are only visible from certain angles.

Bitmap group 0 is displayed by default by most Blakod, and the client uses it for display in certain dialogs. Other groups are reached by animation or bitmap change commands sent from Blakod.

For very long command lines, you can read the command line from a file, like this:

`makebgf @`*cmdfile*

These command files by convention end with the extension `.bbg`, and are edited by the `bbgun` program to make lining up bitmaps easier.

Many objects have graphics that are made up of several pieces; for example, a player consists of bitmaps for the torso, legs, arms, head, and facial features. The client organizes the graphics for a single object as a *base bitmap* and a set of *overlays*. The base bitmap is drawn exactly at the object's position, while each overlay is attached to a *hotspot* on the base bitmap or on another overlay. Despite the name, an overlay may be drawn either before (under) or after (over) the base bitmap, depending on the sign of its hotspot number.

Overlay offsets

You can specify the x and y offsets of an overlay bitmap by putting these numbers in brackets after the bitmap filename, like this:

```
makebgf -o out.bgf 2 a [10, 10] b [50, 100]
```

These offsets are added to the overlay's location when the overlay is displayed.

Hotspots

Each bitmap can have one or more hotspots, which are locations referenced by Blakod to place overlays on bitmaps. For example, you can place a head on a body by putting a neck hotspot in the body bitmap, and then displaying the head overlay attached to the neck hotspot.

Hotspots are specified by putting them after the bitmap filenames, and after the (optional) offsets of the bitmap. The syntax is like this:

```
makebgf -o out.bgf 2 a [10, 10] :1 1 [20, 20] \
                     b [50, 100] :3 2 [10, 10] 4 [20, 20] 7 [1, 1]
```

The *a* bitmap has one hotspot; it is numbered 1 and located at (20, 20). The *b* bitmap has three hotspots, numbered 2, 4, and 7. Hotspots are numbered 1-255 inclusive. The value 0 is reserved to indicate that no hotspot exists. Positive one-byte values (1 to 127) are for overlays (drawn after the main bitmap) and negative one-byte values (-1 to -127) are for underlays (drawn before the main bitmap).

When an overlay is attached to a hotspot in the underlying object, the overlay's position is determined by adding the overlay's offset to the hotspot's location. An overlay can also be attached to a hotspot in another overlay (for example, placing eyes on a head overlay). In this example, the position of the eyes is determined by adding the eye's offset to the eyes' hotspot location (this is given in the head's bgf), and then adding this to the head's hotspot location (this is given in the body's bgf). In other words, the eyes' offset is computed relative to the head's location.

If one overlay A is placed on another overlay B, the two overlays may be drawn in either possible order, depending on the sign of the hotspot in overlay B. Since overlay B might be drawn before or after the base bitmap, there are a total of seven layers of bitmaps that may make up an object: the base bitmap itself makes up one layer, overlays on the base bitmap make up two more, and the remaining layers are overlays placed over or under other overlays. The current system does not support more levels of overlays. While few require even these seven layers, player graphics do, in order to draw body parts and equipped items in just the right order.

4.4 Hotspot editor (`bbgun`)

Bbgun has been rewritten and is now obsolete. However, it comes with a Windows help file describing its use.

4.5 Resource merger (`rscmerge`)

After all the Blakod is compiled, there is one `rsc` file that needs to be sent to the client for each Blakod class. As of this writing, there are over 500 classes, and loading that many `rsc` files into the client at startup is unacceptably slow. A small command-line utility program called `rscmerge` combines all of these `rsc` files into a single file, which by convention we give the extension `.rsb` to distinguish it from other resource files. Thus, in each public distribution, there is only a single `.rsb` file that contains the current version of all resources.

The syntax of `rscmerge` is

`rscmerge -o` *output_filename input_filename input_filename* ...

Wildcard characters are allowed in *input_filename*.

4.6 Room encrypter (`roocrypt`)

We must encrypt `.roo` files before we send them to the public. A command-line utility called `roocrypt` performs this function. The syntax is

`roocrypt` *input_filename output_filename*

The input and output files must be different.

Since the room editor cannot load encrypted rooms, it is convenient to leave rooms in their unencrypted form until the last moment, and then encrypt them all just before releasing them to the public. The client is able to load both encrypted and unencrypted rooms.

Chapter 5

Using the system

5.1 Server configuration

BlakServ has many configuration options which control its behavior. Just about anything that could have been made a compile-time constant has instead been placed in an external file, `blakserv.cfg`, that the server reads upon startup. Several options can be changed while the server continues to run.

The format of `blakserv.cfg` is the same as a Windows `.ini` file except that there is no equals sign between the option name and its value. Comments can be added by starting a line with a semicolon. Like a `.ini` file, configuration options are separated into groups, which are specified by putting the group name in brackets on its own line.

Here is a sample `blakserv.cfg` file:

```
; sample blakserv.cfg file
[Path]
Bof                     loadkod\
Memmap                  memmap\
Rsc                     rsc\
Rooms                   rooms\
Motd                    loadkod\
Channel                 channel\
LoadSave                game\
Forms                   forms\
Kodbase                 .\
PackageFile             .\

[Socket]
Port                    5959
DNSLookup               No

[Channel]
DebugDisk               Yes
ErrorDisk               Yes
```

```
LogDisk              Yes

[Guest]

[Login]
MinVersion           325

[Inactive]

[MessageOfTheDay]

[Credit]

[Session]
MaxActive            250
MaxConnect           400

[Lock]

[Resource]

[Memory]

[Auto]
GarbageTime          320
GarbagePeriod        640
SavePeriod           640

[Email]
Listen               No

[Update]
ClientMachine        meridian59.3do.com
ClientFilename       /pub/m.arq
PackageMachine       meridian59.3do.com
PackagePath          pub/package/

[Console]

[Constants]
Enabled              Yes
Filename             .\blakston.khd

[Portal]
```

```
[Advertise]
File1 latex.avi
URL1 http://meridian.3do.com/meridian
File2 hints.avi
URL2 http://www.3do.com/studio3do/customerservice/hintline.html

[Debug]
```

Below is a description of every configuration option, one table per group.

Path

Name	Type	Default	Dynamic	Description
Bof	String	.	No	The directory with *new* .bof files.
Memmap	String	.	No	The directory to memory map .bof files from.
Rsc	String	.	No	The directory with all .rsc files.
Rooms	String	.	No	The directory with all .roo files.
Motd	String	.	No	The directory with the motd.txt (message of the day) file.
Channel	String	.	No	The directory to write the log, error, and debug channels to.
LoadSave	String	.	No	The directory to load games from and save games to.
Forms	String	.	No	Obsolete.
Kodbase	String	.	No	The directory with kodbase.txt.
PackageFile	String	.	No	The directory with packages.txt

Socket

Name	Type	Default	Dynamic	Description
Port	Integer	9999	No	The port that BlakServ listens for clients on.
MaintenancePort	Integer	9998	No	The port that BlakServ listens for maintenance requests on.
MaintenanceMask	String	198.211.33.48	No	The IP address to listen for maintenance requests on.
DNSLookup	Boolean	No	No	Whether BlakServ performs a reverse DNS lookup on each incoming client or not.
Nagle	Boolean	Yes	No	Whether or not to enable the Nagle algorithm on socket connections (see Internet RFC 896).

Channel

Name	Type	Default	Dynamic	Description
DebugDisk	Boolean	No	No	Whether BlakServ should write debug.txt to disk or not.
ErrorDisk	Boolean	No	No	Whether BlakServ should write error.txt to disk or not.
LogDisk	Boolean	No	No	Whether BlakServ should write log.txt to disk or not.

Guest

Name	Type	Default	Dynamic	Description
Account	String	Guest	No	The account name that is mapped to the guest system.
Credits	Integer	10	No	Obsolete.
Max	Integer	30	Yes	The maximum number of guests allowed on this server at one time.
ServerMin	Integer	30	Yes	The lowest server number guests can log in on.
ServerMax	Integer	55	Yes	The highest server number guests can log in on.
TooMany	String	Too many guests are logged onright now; please try again later.	No	The string sent to a client trying to log on as a guest when this server is already maxed out with guests.

Login

Name	Type	Default	Dynamic	Description
MaxAttempts	Integer	3	No	Number of login attempts allowed before BlakServ hangs up the client.
MinVersion	Integer	0	Yes	The lowest client version number that works with this server setup.
OldVersionStr	String	The game software has been upgraded while you have been online. Logoff and then login again to automatically upgrade your software.	No	The string sent to clients who quit the game and now have an outdated version of the client.
InvalidVersion	Integer	100	No	The maximum client version number which cannot be updated to the latest client configuration automatically.
InvalidVersionStr	String	Your version of the game software is beta; you need to purchase the latest version.	No	The string sent to clients that are too out of date to update to the latest version.

Inactive

Name	Type	Default	Dynamic	Description
Synched	Integer	10	Yes	The number of minutes to wait for a client message in STATE_SYNCHED before automatically disconnecting the socket.
Transfer	Integer	2	Yes	The number of minutes to wait for a client message in STATE_SYNCHED when performing a file transfer before automatically disconnecting the socket.
SelectChar	Integer	10	Yes	The number of minutes to wait for a client message in STATE_GAME before picking a character before automatically disconnecting the socket.
Game	Integer	20	Yes	The number of seconds to wait for a client message in STATE_GAME before automatically disconnecting the socket.

MessageOfTheDay

Name	Type	Default	Dynamic	Description
Default	String		No	The default message of the day.

Credit

Name	Type	Default	Dynamic	Description
DrainAmount	Integer	-1	No	Obsolete.
DrainTime	Integer	1	No	Obsolete.
Warn1	Integer	5	No	Obsolete.
Warn2	Integer	1	No	Obsolete.
Initial	Integer	0	No	Obsolete.
Admin	Integer	25	No	Obsolete.

Session

Name	Type	Default	Dynamic	Description
MaxActive	Integer	10	Yes	The maximum number of logged on users at any time (excluding admins).
MaxConnect	Integer	20	No	The maximum number of logged on users total.
Busy	String	Too many people are logged on right now; please try again later.	No	The message sent to clients unable to login because this server is too busy.

Lock

Name	Type	Default	Dynamic	Description
Default	String	The game is temporarily closed for maintenance, sorry.	No	The message sent to clients unable to enter the game because it was locked by an administrator.

Resource

Name	Type	Default	Dynamic	Description
RscSpec	String	*.rsc	No	The file spec of all resource files to load at startup.

Memory

Name	Type	Default	Dynamic	Description
SizeClassHash	Integer	1997	No	The size of the hash table of loaded Blakod classes.

Auto

Name	Type	Default	Dynamic	Description
GarbageTime	Integer	90	No	When the number of minutes since 1970 mod GarbagePeriod = this number, perform garbage collection.
GarbagePeriod	Integer	180	No	
SaveTime	Integer	0	No	When the number of minutes since 1970 mod SavePeriod = this number, save the game to disk.
SavePeriod	Integer	180	No	
KodTime	Integer	90	No	When the number of minutes since 1970 mod KodPeriod = this number, send a `NewHour` message to the system object.
KodPeriod	Integer	50	No	
InterfaceUpdate	Integer	5	No	The server updates its interface window every this many seconds.
TransmittedTime	Integer	0	No	When the number of seconds since 1970 mod TransmittedPeriod = this number, reset the internal count of the number of bytes written to all sockets.
TransmittedPeriod	Integer	60	No	
ResetPoolTime	Integer	0	No	When the number of minutes since 1970 mod ResetPoolPeriod = this number, free any memory buffers used in BlakServ's network buffering that aren't currently in use.
ResetPoolPeriod	Integer	60	No	
CheckPortalTime	Integer	4	No	When the number of minutes since 1970 mod CheckPortalPeriod = this number, check the socket connected to the Portal server (if enabled). If it's disconnected, try to reconnect.
CheckPortalPeriod	Integer	5	No	

Email

Name	Type	Default	Dynamic	Description
Listen	Boolean	Yes	No	Whether or not to listen for email account creation and deletion requests.
Port	Integer	25	No	The port to listen for email account creation and deletion requests.
AccountCreateName	String	account-create	No	The email account name to use for account creation requests.
AccountDeleteName	String	account-delete	No	The email account name to use for account deletion requests.
LocalMachineName	String	unknown	Yes	The machine name in email account creation and deletion requests. Usually the same as the machine's primary DNS lookup name.

Update

Name	Type	Default	Dynamic	Description
ClientMachine	String	unknown	No	The machine name sent to clients with outdated clients (this machine must be running an ftp server).
ClientFilename	String	unknown	No	The filename to retrieve via ftp from ClientMachine to update the client.
PackageMachine	String	unknown	No	The machine name sent to clients that need to download new data files (this machine must be running an ftp server).
PackagePath	String	unknown	No	This path is prepended by the client to the files it needs to download from PackageMachine.

Console

Name	Type	Default	Dynamic	Description
Administrator	String	Administrator	No	The name used for admin `say` commands typed on the server interface.

Constants

Name	Type	Default	Dynamic	Description
Enabled	Boolean	No	No	Whether the server should try to load constants to use in admin mode.
Filename	String	.\blakston.khd	No	The filename to load constant values from to use symbolic names for numbers in admin mode.

Portal

Name	Type	Default	Dynamic	Description
Enabled	Boolean	No	No	Whether or not to attempt to connect to a Portal server.
Ignore	Boolean	No	No	Whether or not to ignore Portal's feedback and log in all users with correct passwords.
Machine	String	pc2.3do.com	No	The machine to connect to, running a Portal server.
Port	Integer	4949	No	The port on Machine to connect to.
ServerNumber	Integer	1	No	The server number to send to the portal server to identify this server machine.
ErrorReport	String	An error has occurred in verifying your account information; please try again in a few minutes.	No	The string sent to a client that logins in with Portal enabled when there is an error connecting to Portal.

Advertise

Name	Type	Default	Dynamic	Description
File1	String	ad1.avi	Yes	The filename of the animation sent to the client for advertisement 1.
Url1	String	http://www.3do.com	Yes	The URL sent to the client for it to visit if the user clicks on advertisement 1.
File2	String	ad1.avi	Yes	The filename of the animation sent to the client for advertisement 2.
Url2	String	http://meridian.3do.com/meridian	Yes	The URL sent to the client for it to visit of the user clicks on advertisement 2.

Debug

Name	Type	Default	Dynamic	Description
SMTP	Boolean	No	Yes	Whether or not to print debugging information in the email listening module.
CanMoveInRoom	Boolean	No	Yes	Whether or not to print debugging information in the CanMoveInRoom function.
Heap	Boolean	No	Yes	Whether or not to print debugging information in the memory allocation and freeing functions.
TransmittedBytes	Boolean	No	Yes	Whether or not to print out the number of bytes sent over all sockets every minute.
Hash	Boolean	No	Yes	Whether or not to print out debugging information in the hash calculation function.
Portal	Boolean	No	Yes	Whether or not to print out debugging information in the Portal connection routines.

5.2 Administrator mode

Users with administrator accounts have access to the total system. They can control the game down to the Blakod object and list node level. Below is a description of every administrator command.

Garbage (no parameters) Immediately perform garbage collection.

Who (no parameters) Show all connected clients.

Lock (string) Lock the game so that new client connections are not allowed into game mode, and instead sent the specified string as the reason.

Unlock (no parameters) Unlock the game so that anyone can enter game mode.

Mail (no parameters) Obsolete.

Page (no parameters) Plays a sound on the machine running BlakServ.

Say (string) Sends the string to all users in admin mode.

Read (string) Reads the indicated filename and parses it as a list of admin commands, performing them immediately.

Show command

Show Status (no parameters) Shows the uptime of the server, number of objects, list nodes, strings, and whether the game is locked.

Show Memory (no parameters) Shows the memory usage by server memory category, including a total.

Show Called (integer) Shows the specified number of most called Blakod messages.

Show Object (integer) Shows the properties of the specified object.

Show ListNode (integer) Shows the specified list node.

Show List (integer) Treating the number as the first list node of a complete list, shows the complete list.

Show Users (no parameters) Shows every account number and associated object ids.

Show User (integer) Shows the account number associated with the associed object id (which must be of the user class).

Show Usage (no parameters) Shows the number of regular users and guests logged on.

Show Accounts (no parameters) Shows every account number and account name in the system.

Show Account (integer) Shows the specified account number and the associated account name.

Show Resource (string) Shows the string value of the specified resource name.

Show Dynamic Resources (no parameters) Shows every dynamic resource (player name) in the system.

Show Timers (no parameters) Shows every timer id, time remaining, and associated messages.

Show Timer (integer) Shows the specified timer id, its time remaining, and the message that will be called when the timer goes off.

Show Configuration (no parameters) Shows every configuration value in the system.

Show String (integer) Shows the specified string id and associated string value.

Show SysTimers (no parameters) Shows every built in system timer, and when they will next go off.

Show Calls (integer) Shows the specified number of most called C code functions (from Blakod).

Show Message (string, string) Shows the parameters and Blakod comment about the specified class and message handler.

Show Class (string) Shows the specified class name and its class variables.

Show Packages (no parameters) Shows every filename specified in packages.txt that are sent to clients with old data files.

Show Constant (string) Shows the value of the specified admin constant name.

Show Transmitted (no parameters) Shows the number of bytes written on all sockets since the last time the count was reset (through the system timer).

Show Table (integer) Shows the specified hash table id and every entry in the table.

Show Name (string) Shows the user object id associated with the specified user name.

Show References (integer) Shows every object that has a property that references the specified object id.

Show Instances (string) Shows every object id of the specified class name.

Show Protocol (no parameters) Shows the number of times each message type has been received from any client.

Set command

Set Object (integer, string, Blakod value) Sets the specified property of the specified object id to the specified Blakod value.

Set Account Name (integer, string) Sets the specified account number to have the specified user name.

Set Account Password (integer, string) Sets the specified account number to have the specified password.

Set Account Credits Obsolete.

Set Account Object (integer, integer) Creates a new association between the specified account number and the specified object id (which must be class user).

Set Config Integer (string, string, integer) Sets the configuration option of the specified configuration group to the specified integer (the configuration option must be of type integer).

Set Config String (string, string, string) Sets the configuration option of the specified configuration group to the specified integer (the configuration option must be of type string).

Set Config Boolean (string, string, boolean) Sets the configuration option of the specified configuration group to the specified integer (the configuration option must be of type boolean).

Create command

Create Account (string, string, string) Creates a new account with the specified type (user, admin, dm, or guest), name, and password.

Create Automated (string, string) Creates a user type account and game user object with the specified account name and account password.

Create User (integer) Creates a game user object associated with the specified account id.

Create Admin (integer) Creates a game admin object associated with the specified account id.

Create DM (integer) Creates a game dm object associated with the specified account id.

Create Object (string) Creates a new object of the specified class.

Create List Node (Blakod value, Blakod value) Creates a new list node with the specified first and rest values.

Create Timer (integer, string, integer) Creates a new Blakod timer with the specified object id, message name, and milliseconds until it goes off.

Create Resource (string) Creates a new dynamic resource with the given string value.

Delete command

Delete Timer (integer) Deletes the specified timer id.

Delete Account (integer) Deletes the specified account id and associated game objects.

Delete User (integer) Deletes the association between the specified object id (which must be a user class object) and the account associated with it.

Send command

Send Object (integer, string) Sends the specified message to the specified object id.

Send Users (string) Sends the string as an in game broadcast to all users.

Trace command

Trace On Obsolete.

Trace Off Obsolete.

Add command

Add Credits Obsolete.

Kickoff command

Kickoff All (no parameters) Sets any client in game mode back to the main menu mode.

Kickoff Account (integer) If a logged in client is using the specified account id and is in game mode, it is set back to the main menu mode.

Hangup command

Hangup Account (integer) If a logged in client is using the specified account id, it is disconnected.

Hangup Session (integer) Disconnects the specified session id.

Reload command

Reload System (no parameters) Performs garbage collection, saves the game, unloads all Blakod, then reloads the Blakod, message of the day, and saved game.

Reload Game Obsolete.

Reload MOTD (no parameters) Reloads the message of the day from motd.txt.

Reload Packages (no parameters) Reloads the list of files to send to clients with outdated data files from packages.txt.

Reload Protocol (no parameters) Unloads and reloads sprocket.dll.

Reload Portal (no parameters) If Portal is enabled, checks the socket connection and attempts to reconnect if it is disconnected.

Disable command

Disable Systimer (integer) Disables the specified system timer id.

Enable command

Enable Systimer (integer) Enables the specified system timer id, if it has been previously disabled.

Terminate command

Terminate NoSave (no parameters) Terminates the server immediately.

Terminate Save (no parameters) Saves the game state and then terminates the server.

Save command

Save Game (no parameters) Saves the game state to disk.

Save Configuration (no parameters) Saves all configuration parameters to blakserv.cfg.

5.3 The build system

Each part of the system (client, server, etc.) occupies a separate directory in the source tree. Under each source directory is a directory named `nt` into which all object code and executables go as they are built. All C code except the room editor is compiled with Microsoft Visual C++; the editor uses Borland C++.

The build system requires that the file "build.bat" exist in the path. All build commands must be entered from the command shell 4nt. Building the Blakod complier requires that the GNU programs flex and bison reside in the path.

When installing the source code on a new system, some paths must be set by hand. A line in build.bat points to the root of the source tree. In the source tree root directory, the file common.mak points to the Microsoft C compiler. Another line in common.mak points to a directory in the path (called \blakbin by default) where intermediate programs are placed as they're built. Several lines in the windeu.mak file in the roomedit directory point to pieces of the Borland C++ compiler.

To build a piece of the system, run 4nt, change to the piece's directory, and type `build`. By default, this builds a debugging version of the program. To build an optimized version, type `build RELEASE=1`. The command `build FINAL=1` in the client or module directories builds an optimized version with all debugging strings removed from the target. To build the room editor, type `make -f windeu.mak` in the roomedit directory.

Dependencies

Building Blakod requires that the Blakod compiler is built. The modules import functions from the client, so the client needs to be built first. The client itself links with libraries for the wavemix and crusher DLLs, so these need to be built before the client. Building graphics (in the resource directory) uses the makebgf program.

Other than these dependencies, components may be built in any order.

5.4 Adding new artwork

To add new artwork, first save it as a set of bitmaps using the standard BlakSton palette, and copy the bitmaps to the correct subdirectory under the resource directory: the textures subdirectory for wall, floor, and ceiling textures, and the graphics subdirectory for everything else. Add a line to the list of targets in the build.mak file.

For textures, add an entry to the build.mak file that lists the source bitmap for the new bgf file. Use the -w command line option to makebgf for wall bitmaps to rotate them appropriately.

For other graphics, create a bbg file using bbgun to specify how the bitmaps are are assembled into a bgf file. You also need to reference the new bgf file from the Blakod for the new object (typically in the vrIcon property).

When you type build in the appropriate subdirectory, the build script will run makebgf on the new bitmaps, and produce a bgf file. This file will go into the bin subdirectory of the resource directory.

5.5 Adding new rooms

First, create a new roo file with the room editor and save it. Next, locate the appropriate place in the class hierarchy for the new room (usually under the room or monsroom classes). Create a new kod file for the room there, add a line to build the kod file in the build.mak file in that directory, and reference the new roo file in the prRoom property of the kod file. In the blakston.khd header file, reserve a new identifier for the room, and enter this in the piRoom_num property of the class. Finally, in the CreateAllRoomsIfNew function of the System class, add a line that creates the new room.

To actually create the new room object, enter the administrator command `send object 0 createallroomsifnew` in the server.

To connect the room to other existing rooms, add handlers for the CreateStandardExits and SomethingTryGo messages. The contents of these message handlers can be copied from those in existing room Blakod.

Before the roo file is released to the public, it should be encrypted with the roocrypt utility.

5.6 Perparing a release

To assemble a client release for the public, a complete image of all client files must be assembled in one place, with the same directory structure as the installation on client machines. To summarize, the client executable and INI file reside in the top level directory, while all room files, graphics, sounds, and DLLs reside in the "resource" subdirectory. Each of the room files should be encrypted with the roocrypt utility before the release is built; no other files need to be processed.

The client setup should go under a directory called "program". Parallel to this is a directory called "system" that receives the files that will be installed in the Windows system directory on client machines. These files include wininet.dll and urlcache.dll, two files used by the Microsoft implementation of ftp, used for client updates.

The installation system uses InstallShield3 and a modified sample script. This script first checks the operating system (Windows 95 or Windows NT), and ensures that the user's selected destination directory has enough available disk space. It creates registry entries under the Studio 3DO vendor name and Meridian 59 application name, for uninstallation purposes. It then installs client files in the destination directory, and the shared files in the Windows system directory. Next it installs the Heidelberg-Normal font by directly modifying registry entries. Finally, it creates a shortcut in the Start menu for the client program.

The InstallShield script also displays two text files during installation. These are called "readme.txt" and "install.txt". The readme.txt file contains general information on running the game. The install.txt file is a licensing agreement. These files reside in the same directory as the InstallShield script, and they are placed in the root directory of the CD.

All that is required to build a client installation is to copy the client and shared files as described above, then change to the install directory and type "build". The makefile will invoke the InstallShield utilities to set up the final installation files.

In order to make the installer run automatically when the CD is placed in the drive, a file called autorun.inf is typically placed on the CD by someone outside the development team. This file references an icon (meridian.ico) which is also placed in the root directory of the CD, and which shows up as the icon of the CD drive in the Windows explorer. The autorun file also references the setup executable that should run when the CD is put in the drive.

Appendix A

Protocols

All messages are binary, and all data fields are stored in little-endian byte order, unless otherwise specified. To describe a message, we use the conventions shown in the following example:

Bytes in field	Description of field
4 bytes	number of <**entry**>s (= n)
$4n$ bytes	<**entry**>s

<**entry**> =

4 bytes	per-entry information

<**entry**>$*$	zero or more instances of <**entry**>

Sample message

<**BP_TEST**> <**data**>
<**data**> =

n bytes	data for this message

A message is described in sequential order. A token within angle brackets (**<>**) is a nonterminal symbol that is defined elsewhere in the specification.

A.1 Client/server protocol

The client and the server communicate via two similar protocols. While the client is logging in, the "login mode" protocol handles getting the player into the game, and performing any necessary dynamic updates. The "game mode" protocol takes over once the player has entered the game. In addition, many of the Meridian-specific game messages are split off into a "user command" sub-protocol within the game mode protocol.

Each message is in the following format:

<**length**>
<**security**>
<**sequence number**>
<**message type**>
<**data**>

<**length**> =
2 bytes length of <**data**>

<**security**> =
In messages from the server to the client, this is always 0.
In client messages, it's the following expression:
<**length**> XOR (<**message type**> $\ll$ 4) XOR <**checksum**> XOR <**random output**>

<**sequence number**> =
1 byte
In login mode, this is always 0.
In game mode, this is a monotonically increasing value that increments at each server garbage collection. The server rejects all messages with old sequence numbers. This prevents client messages from using stale object numbers.

<**message type**> =
1 byte type of message

<**data**> =
n bytes message-dependent data

<**checksum**> =
2 bytes CRC16 of <**data**>

<**random output**> =
2 bytes
This is a pseudo-random number generated for each message from the client to the server. The server and client each step their generators in sync, and the server rejects any message whose <**random output**> field doesn't match. This prevents malicious users from replaying messages.

Each message below is described by its message type, per-message data, and a brief description of what the message is used for.

A.1.1 Login mode protocol

Login protocol message types are constants that begin with AP.

Messages from the client to the server:

<**AP_LOGIN**> <**version**> <**sysinfo**> <**username**> <**password**>
Player wants to log on.

<**version**> =

1 byte	high byte of version number
1 byte	low byte of version number

<**sysinfo**> =

4 bytes	operating system identifier
4 bytes	operating system major version
4 bytes	operating system minor version
4 bytes	amount of physical memory on system
4 bytes	processor identifier
2 bytes	width of screen in pixels
2 bytes	height of screen in pixels
12 bytes	reserved (set to 0 for upward compatability)

<**AP_REQ_GAME**> <**download time**>
Player wants to enter the game.

<**download time**> <**file time**> for last downloaded file

<**AP_REQ_ADMIN**>
Player wants to go into administrator mode.

<**AP_REQ_MENU**>
Requests main menu info (obsolete, but still used trivially).

<**AP_RESYNC**>
Resynchronize; a protocol error has occurred.

<**AP_PING**>
Client is active (sent during downloads to prevent timeouts).

Messages from the server to the client:

<**AP_GETLOGIN**>
Prompt user for login information.

<**AP_LOGINOK**> <**account type**>

Login accepted.
<account type> =

1 byte	type of account; normal user = 0, admin = 1, guest = 2

<AP_LOGINFAILED>
Login rejected.

<AP_GAME>
Go into client's game state.

<AP_ADMIN>
Go into client's administrator mode.

<AP_GETCHOICE> <seed1> <seed2> <seed3> <seed4> <seed5>
Display main menu (obsolete); used to initialize random number generators.
<seed> =

4 bytes	random number seed

<AP_MESSAGE> <string> <action>
Display error message.
<action> =

1 byte	what to do after displaying message
0	continue normally
1	log off

<AP_ACCOUNTUSED>
Account is already in use.

<AP_TOOMANYLOGINS>
Too many login attempts.

<AP_TIMEOUT>
Login timed out.

<AP_CREDITS> <number>
User has given number of credits (obsolete).

<AP_DOWNLOAD> <number of files> <machine> <path> <file>*
Begin a file download.
<number of files> =
2 bytes

<machine> =

<string>	name of machine to ftp files from

<**path**> =

<**string**>	pathname where files reside on <**machine**>

<**file**> =

4 bytes	file time
4 bytes	<**file flags**>
<**string**>	filename

<**file flags**> =

1 byte	what to do with the file

bits 0-1: what to do with file ("command")

0	ftp file
1	delete file (machine, path, file time ignored)

bits 2-4: local location of file ("location")

0	resource directory
1	client directory
2	Windows directory
3	Windows system directory
4	help subdirectory
5	mail subdirectory
6	client directory (reserved to identify advertisement files)

bit 5:

1	if file applies to guest accounts

The files must appear in increasing file time order.

<**AP_NOCREDITS**>

User is out of credits (obsolete).

<**AP_RESYNC**>

Resynchronize; a protocol error has occurred.

<**AP_DELETERSC**> <**strings**>

Delete given resource files.

<**AP_GETCLIENT**> <**ftp string**> <**fname string**>

New version of client needed.

<**ftp string**> =

<**string**>	name of ftp server to connect to

<**fname string**> =

<**string**>	name of filename to retrieve

<AP_GUEST> <status> <min range> <max range>
Guest trying to log in.

<status> =

1 byte	0 if it's OK to log in here; 1 if not

<min range> =

4 bytes	low end of range of available server numbers

<max range> =

4 bytes	high end of range of available server numbers

<strings> =

2 bytes	number of strings
<string>$*$	

<string> =

2 bytes	length of string ($= n$)
n bytes	string itself (NOT null terminated)

<number> =

4 bytes	

<time> =

4 bytes	UNIX time (number of seconds since 12:00 am, Jan 1 1970)

A.1.2 Game mode protocol

Login protocol message types are constants that begin with BP.

Messages from the client to the server:

<BP_RESYNC>
Resynchronize; a protocol error has occurred.

<BP_PING>
Client is active (used to prevent timeouts).

<BP_LOGOFF>
Logoff.

<BP_REQ_QUIT>
Player wants to quit game.

<BP_SEND_ROOM_CONTENTS>
Send room contents.

<BP_SEND_PLAYER>
Send player's location and other information.

<BP_SEND_STAT_GROUPS>
Send info on all statistic groups.

<BP_SEND_STATS> <group>
Send given group of game statistics.

<BP_SEND_PLAYERS>
Send list of players currently logged on.

<BP_SEND_CHARACTERS>
Send list of characters to choose from.

<BP_SEND_SPELLS>
Send list of available spells.

<BP_USE_CHARACTER> <object>
Player has selected character to use in game.

<BP_REQ_ADMIN> <string>
Admin command.

<BP_REQ_DM> <type> <string>
DM command.
<type> =

1 byte	command type
1	go to room (string = room id constant or object id)
2	go to player (string = object id)
3	get player (string = object id)

<BP_SAY_BLOCKED> <sender id>
Player is blocking message sent to him (sent in reply to <**BP_SAID**>).
<sender id> =

<object>	object ID of message's original sender

<BP_SEND_ENCHANTMENTS> <enchant type>
Send enchantment information.

<BP_CHANGE_PASSWORD> <old password> <new password>
Change password.

<old password> =
string — old password

<new password> =
string — new password

<BP_AD_SELECTED> <num>
Player viewed an advertisement (used to collect marketing data).
<num> =
1 byte — advertisement number, 1 = first one

<BP_REQ_MOVE> <coords> <speed> <room id>
Move player.
<speed> =
1 byte — number of server squares per ten seconds
<room id> =
<object> — object id of player's currentroom

<BP_REQ_TURN> <object> <angle>
Player turned object to given angle.

<BP_REQ_INVENTORY>
Send player's inventory and list of objects in use.

<BP_SEND_OBJECT_CONTENTS> <object>
Look inside given object.

<BP_REQ_LOOK> <object>
Examine given object.

<BP_REQ_USE> <object>
Use given object.

<BP_REQ_UNUSE> <object>
Stop using given object.

<BP_REQ_ATTACK> <attack info> <object>
Attack given object.
<attack info> =
1 byte — Reserved; always 1.

<BP_SAY_TO> <say type> <string>
Say something.

<BP_SAY_GROUP> <object list> <string>

Say to arbitrary group of people.

<BP_REQ_GET> <object>
Get given object.

<BP_REQ_DROP> <object>
Drop given object.

<BP_REQ_PUT> <object1> <object2>
Put **<object1>** inside **<object 2>**.

<BP_REQ_OFFER> <receiver> <object list>
Initiate trade of given objects.
<receiver> =
<object> object to receive offered objects

<BP_CANCEL_OFFER>
Cancel current trade offer.

<BP_REQ_COUNTEROFFER> <object list>
Respond to an offer with a list of objects to exchange.

<BP_ACCEPT_OFFER>
Accept offer.

<BP_REQ_GO>
Try to enter a door.

<BP_REQ_BUY> <object>
Get list of buyable items from given object.

<BP_REQ_BUY_ITEMS> <seller> <object list>
Buy given objects.
<seller> =
<object> object to buy from

<BP_REQ_APPLY> <object1> <object2>
Use object1 on object2.

<BP_REQ_CAST> <spell object> <targets>
Cast a spell.
<targets> =
<object list> list of target objects

<BP_ACTION> <action>

Perform simple action or facial expression.

<**action**> =

1 byte	action identifier

<**BP_CHANGE_DESCRIPTION**> <**object**> <**string**>

Change given object's description.

<**BP_REQ_ACTIVATE**> <**object**>

Activate given object in the room.

<**BP_USERCOMMAND**> <**command**> <**data**>

User command (generic non-standard command).

<**command**> =

1 byte	command message type
<**data**>	per-command data; see section **??**

<**BP_REQ_GET_MAIL**>

Get all new mail messages.

<**BP_DELETE_MAIL**> <**index**>

Mail message received; server can delete mail message.

<**index**> =

4 bytes	message's server index (sent in <**BP_MAIL**> message).

<**BP_SEND_MAIL**> <**client mail message**>

Player wants to send a mail message.

<**BP_REQ_LOOKUP_NAMES**> <**num names**> <**string**>

Return object numbers for given player name strings.

<**num names**> =

2 bytes	number of names in <**string**>
<**string**>	contains a sequence of player names, separated by commas

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<**BP_REQ_ARTICLES**> <**newsgroup id**>

Get news article indexes for a newsgroup.

<**BP_REQ_ARTICLE**> <**newsgroup id**> <**article index**>

Get news article's text.

<**BP_POST_ARTICLE**> <**newsgroup id**> <**title string**> <**body string**>

Post news article.

The following two messages are prefixed with <**BP_SYSTEM**>. The remainder of the message, as described below, is passed to the unique system object on the server.

<BP_SEND_CHARINFO>
Send character characteristics and abilities.

<BP_NEW_CHARINFO> <object> <name string> <description string> <new charinfo>
Character's new information.

One value is sent for each item in the server's **<BP_CHARINFO>** message. If the item was a multiple-choice, then the value is the index of the chosen item. If the item was a number, then the value is the chosen value of the number.

Messages from the server to the client:

<BP_RESYNC>
Resynchronize; a protocol error has occurred.

<BP_ECHO_PING>
Reply to **<BP_PING>**.

<BP_SYS_MESSAGE> <string>
Display system text message.

<BP_ROOM_CONTENTS> <room> <object location list>
Contents of current room.

<BP_OBJECT_CONTENTS> <object> <object contents list>
Contents of given object.

<BP_QUIT>
Quit game.

<BP_WAIT>
Don't allow player input until a **<BP_UNWAIT>** is received.

<BP_UNWAIT>
Allow player input again.

<BP_PLAYERS> <player info list>
List of players currently logged on.

<BP_PLAYER_ADD> <player info>
New player has logged on.

<BP_PLAYER_REMOVE> <object>
Player has logged off.

<BP_CHARACTERS> <character list> <motd> <ad info>
List of characters player should select from.
<motd> =

string	message of the day

<ad info> =

1 byte	number of ads
<ad>*	

<ad> =

<string>	filename for ad graphic
<string>	URL associated with ad

<BP_SPELLS> <num spells> <spell>*
List of spells available to player.
<numspells> =

2 bytes	number of spells in next field

<BP_SPELL_ADD> <spell>
Add spell.

<BP_SPELL_REMOVE> <object>
Remove spell.

<BP_CHARINFO> <charinfo list>
Character creation information.

<BP_LOAD_MODULE> <DLL>
Load DLL.

<BP_UNLOAD_MODULE> <DLL>
Unload DLL.

<BP_ADMIN> <string>
Result of previous admin command.

<BP_CHANGE_RESOURCE> <resource> <string>
Change resource's value, or add if not already present.

<BP_CHARINFO_OK>
Character creation info is valid.

<BP_CHARINFO_NOT_OK>
Character creation info is invalid.

<BP_PASSWORD_OK>
Password changed.

<BP_PASSWORD_NOT_OK>
Password not changed; old password doesn't match.

<BP_INVENTORY_ADD> <object desc>
Add given object to inventory.

<BP_INVENTORY_REMOVE> <object>
Remove given object from inventory.

<BP_CREATE> <object info>
Create object.

<BP_REMOVE> <object>
Remove object.

<BP_MOVE> <object> <coords> <speed>
Move object.
<speed> =

1 byte	number of server squares per ten seconds

A value of 0 means teleport the object instantaneously.

<BP_TURN> <object> <angle>
Turn object to given angle.

<BP_USE> <object>
Display given object as in use.

<BP_UNUSE> <object>
Stop displaying given object as in use.

<BP_CHANGE> <object desc> <animation> <overlays>
Change object.

<animation>	how to animate object when it moves
<overlays>	overlays for object when it moves

<BP_LOOK> <object desc> <flags> <resource> <printf-param>$*$
Display object's description.
<flags> =

1 byte	bit flags for object description
bit 0	1 if player can set description of object

<BP_MESSAGE> <source> <resource> <printf-param>*
Display text message.
<source> =

1 byte	source of message
0	from system
1	from another player

<BP_SAID> <source obj> <source name> <say type> <resource> <printf-param>*
Message from another player.
<source obj> =

<object>	source object of message

<source name> =

<resource>	name resource of source object

<BP_EFFECT> <effect num> <effect-dependent data>
Perform special effect.
<effect num> =

2 bytes	effect to perform
effect_invert	
4 bytes	number of milliseconds to keep screen colors inverted
effect_shake	
4 bytes	number of milliseconds to shake player's view
effect_paralyze	prevent player from moving
effect_release	allow player to move
effect_blind	make player blind
effect_see	remove blindness

<BP_PLAYER> <player object> <icon resource> <name resource> <location> <lighting> <background> <wading>
Player's information.
<location> =

4 bytes	current room id number
4 bytes	current room resource number
4 bytes	current room name resource id number
4 bytes	room security check (number in room file)

<lighting> =

<light>	ambient light level
<light>	player's light level

<background> =

<resource>	background bitmap for room

<wading> =

<resource> sound for wading/splashing in room

<BP_INVENTORY> <object contents list>
Player's inventory.

<BP_USE_LIST> <object list>
List of objects player is using.

<BP_STAT_GROUPS> <num groups> <group info>*
List of stat groups.
<num groups> =
1 byte number of **<group info>**s to follow

<group info> =
<resource> resource of stat group name

<BP_STAT_GROUP> <group> <num stats> <stat>*
Group of game statistics.
<num stats> =
1 byte number of **<stat>**s to follow
All stats in a group must be of the same type (see **<stat>**).

<BP_STAT> <group> <stat>
Update given game statistic.

<BP_OFFER> <sender> <object contents list>
Player received an offer.
<sender> =
<object desc> object which made offer

<BP_OFFERED> <object contents list>
Player made an offer; this is list of offered items.

<BP_OFFER_CANCELED>
Current offer was canceled.

<BP_COUNTEROFFER> <object contents list>
Counteroffer was made.

<BP_COUNTEROFFERED> <object contents list>
Player made a counteroffer; this is list of offered items.

<BP_BUY_LIST> <object desc> <server buy list>
Items available to buy from given object.

<**BP_PLAY_WAVE**> <**resource**> <**object**> <**sound flags**>
Play wave file originating from given object.
If object = 0, should originate from player.
<**sound flags**> =

1 byte	change the way the sound is played
bit 0	1 if sound should repeat while player is in current room

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<**BP_PLAY_MUSIC**> <**resource**>
Play room music.

<**BP_LIGHT_AMBIENT**> <**light**>
Set ambient light level.

<**BP_LIGHT_PLAYER**> <**light**>
Set light level at player.

<**BP_BACKGROUND**> <**resource**>
Set background bitmap in room.

<**BP_SHOOT**> <**icon resource**> <**animation**> <**source object**>
<**destination object**> <**speed**>
Shoot; move bitmap continuously from source to destination.
<**speed**> =

1 byte	number of server squares per second

<**BP_PLAYER_OVERLAY**> <**hotspot**> <**object desc**>
Add or change player overlay (bitmap drawn over graphics window).

The object id in <**object desc**> identifies the overlay,
e.g. 1 = left hand, etc. It can be in the range 1 .. NUM_PLAYER_OVERLAYS.

<**hotspot**> =

1 byte	Location to place player overlay
0	Remove overlay.
hotspot_nw	upper left corner of graphics window
hotspot_n	centered horizontally on middle of top side of graphics window
hotspot_ne	upper right corner of graphics window
hotspot_e	centered vertically on middle of right side of graphics window
hotspot_se	lower right corner of graphics window
hotspot_s	centered horizontally on middle of bottom side of graphics window
hotspot_sw	lower left corner of graphics window
hotspot_w	centered vertically on middle of left side of graphics window
hotspot_center	centered on graphics window

<**BP_SECTOR_MOVE**> <**type**> <**sector id**> <**height**> <**speed**>

Raise or lower sector.

<**type**> =

1 byte	animation type (ANIMATE_FLOOR_LIFT or ANIMATE_CEILING_LIFT).

<**height**> =

2 bytes	final height of sector (1 server square = 64)

<**speed**> =

1 byte	height units per second to move sector (0 = infinite speed)

<**BP_WALL_ANIMATE**> <**wall id**> <**animation**> <**wall effect**>

Animate wall texture.

<**wall id**> =

2 bytes	wall to animate

<**wall effect**> =

1 byte	what to do to wall after animation is finished
0	do nothing
1	make wall passable
2	make wall impassable
3	make normal wall passable and invisible

<**BP_SECTOR_ANIMATE**> <**sector id**> <**animation**> <**sector effect**>

Animate sector.

<**sector effect**> =

1 byte	reserved; must be 0

<**BP_CHANGE_TEXTURE**> <**id**> <**texture**> <**flags**>

Change texture.

<**id**> =

2 bytes	sector or wall to change

<**texture**> =

2 bytes	new texture number

<**flags**> =

1 byte	which elements to change
bit 0	1 to change above wall texture
bit 1	1 to change normal wall texture
bit 2	1 to change below wall texture
bit 3	1 to change floor texture
bit 4	1 to change ceiling texture

<**BP_SECTOR_LIGHT**> <**sector id**> <**type**>

Change sector lighting.

<type> =

1 byte	type of lighting change
1	turn flickering on
2	turn flickering off

<BP_ADD_ENCHANTMENT> <enchant type> <object desc>
Add display enchantment.

<BP_REMOVE_ENCHANTMENT> <enchant type> <object>
Remove display enchantment.

<BP_ADD_BG_OVERLAY> <bg overlay>
Add background overlay.

<BP_REMOVE_BG_OVERLAY> <object>
Remove background overlay.

<BP_CHANGE_BG_OVERLAY> <bg overlay>
Change background overlay.

<BP_LIGHT_SHADING> <light> <angle> <y coord>
Set directional lighting parameters.

<light>	directional light level
<angle>	angle in xy plane of light source

<y coord> =

2 bytes	y coordinate of light source (in pixels; 0 = on horizon, positive = up)

<BP_MAIL> <server mail message>
Contents of next mail message.
If the number of recipients is 0, there is no next mail message.

<BP_LOOKUP_NAMES> <num objects> <object>∗
Return object numbers from a **<BP_REQ_LOOKUP_NAMES>** request.
<num objects> =

2 bytes	number of **<object>**s

If an object number is 0, the lookup failed for that name.

<BP_LOOK_NEWSGROUP> <newsgroup id> <permission> <object desc> <resource> <printf-param>∗
Description of newsgroup.
<permission> =

1 byte	Player's permissions with this newsgroup
bit 0	1 if player can read group
bit 1	1 if player can post to group

<BP_ARTICLES> <newsgroup id> <part> <num articles> <article header>∗
List of newsgroup's articles.

<num articles> =

2 bytes	number of **<article header>**s

<BP_ARTICLE> <string>
Newsgroup article contents.

Primitives:

<newsgroup id> =

2 bytes	unique identifier of newsgroup

<article header> =

<article index>	index number of article
<time>	time article was posted
<string>	name of poster
<string>	title string, limited to 52 bytes including length

<article index> =

4 bytes	index number of article

<time> =

4 bytes	number of seconds since midnight, January 1, 1996

<character list> =

2 bytes	number of characters in list
<char desc>∗	descriptions of characters

<char desc> =

4 bytes	object id
<string>	character's name
1 byte	extra info
0	character has been in the game before
1	character is new

<charinfo list> =
<face info>
<spell info>
<skill info>

<face info> =

<translations>	allowed hair palette translations
<translations>	allowed face palette translations
<hair info>	male hair choices

<**color info**>	male face choices
<**hair info**>	female hair choices
<**color info**>	female face choices

<**translations**> =

1 byte	number of palette translations
1 byte∗	each palette translation

<**hair info**> =

4 bytes	number of hair choices
<**resource**>∗	icon resources of hair choices

<**color info**> =

<**resource**>	icon resource of head
4 bytes	number of eye choices
<**resource**>∗	icon resources of eye choices
4 bytes	number of nose choices
<**resource**>∗	icon resources of nose choices
4 bytes	number of mouth choices
<**resource**>∗	icon resources of mouth choices

<**spell info**> =

4 bytes	number of spells
<**spell info one**>∗	

<**spell info one**> =

4 bytes	spell ID
<**resource**>	spell's name resource
<**resource**>	spell's description resource
4 bytes	cost of selecting spell

<**skill info**> =

4 bytes	number of skills
<**skill info one**>∗	

<**skill info one**> =

4 bytes	skill ID
<**resource**>	skill's name resource
<**resource**>	skill's description resource
4 bytes	cost of selecting skill

<**new charinfo**> =

1 byte	gender, 1 = male, 2 = female
2 bytes	number of face parts = 5
<**resource**>	head icon resource

<**resource**>	hair icon resource
<**resource**>	eye icon resource
<**resource**>	nose icon resource
<**resource**>	mouth icon resource
1 byte	selected hair palette translation
1 byte	selected face palette translation
2 bytes	number of stats = 6
4 bytes	might value
4 bytes	intellect value
4 bytes	stamina value
4 bytes	mysticism value
4 bytes	agility value
4 bytes	aim value
2 bytes	number of spells chosen
4 bytes∗	spell ID
2 bytes	number of skills chosen
4 bytes∗	skill ID

<**server mail message**> =

4 bytes	message's server index
<**string**>	sender's name
<**time**>	time message sent
2 bytes	number of recipients
<**string**>∗	recipients' names
<**resource**>	format string for mail message
n bytes	<**printf-param**>∗

<**client mail message**> =

2 bytes	number of recipients
<**object**>∗	recipient object ids
<**string**>	body of message

<**part**> =

1 byte	number of this part of message
1 byte	highest numbered part in this message

This acts as a "part x of y" label on the message. The parts must arrive consecutively and in order.

<**light**> =

1 byte	light intensity; 0 = dark, 64 = full intensity

<**spell**> =

4 bytes	spell's object id number
4 bytes	spell's icon resource id number
4 bytes	spell's name resource id number
<**animation**>	

1 byte	number of target objects for spell (should be 0 or 1)
1 byte	school number (1 = first school)

<**server buy list**> =

2 bytes	number of objects in list
<**server buy item**>*	

<**server buy item**> =

<**object desc**>	
4 bytes	cost of item

<**object contents list**> =

2 bytes	number of objects in list
<**object desc**>*	

<**object desc**> =

4 bytes	object id number
4 bytes	object icon resource id number
4 bytes	object name resource id number
<**object flags**>	
<**animation**>	
<**overlays**>	overlay bitmaps for object

If object id number contains CLIENT_TAG_NUMBER (= 0x1) in its upper 4 bits, then instead the format is <**object desc**> =

4 bytes	object id number
4 bytes	amount of object
4 bytes	object icon resource id number
4 bytes	object name resource id number
<**object flags**>	
<**animation**>	
<**overlays**>	overlay bitmaps for object

<**object flags**> =

bits 0-1	nomoveon type
0	player can move onto this object
1	player can't move onto this object
2	object is a teleporter
bit 2	1 = player
bit 3	1 = legal attack target
bit 4	1 = object can be picked up
bit 5	1 = container
bit 6	1 = object can't be examined
bit 9	1 = legal offer target
bit 10	1 = legal buy source

bit 11	1 = can be activated
bit 12	1 = can be applied to another object
bit 13	1 = player has safety on (sent for self only)
bits 14-16	**<player flags>**
bits 17-21	**<drawing effect flags>**

<player flags> =

0x1	murderer
0x2	outlaw
0x3	DM
0x4	creator

<drawing effect flags> =

0x00	no effects
0x01	25% translucency
0x02	50% translucency
0x03	75% translucency
0x04	all black
0x05	invisible

<object location list> =

2 bytes	number of objects in room
<object info>∗	

<object info> =

<object desc>	
<coords>	object's location in room
<angle>	angle object is facing
<animation>	how to animate object when it moves
<overlays>	overlays for object when it moves

<object list> =

2 bytes	number of objects in list
<object>∗	

<player info list> =

2 bytes	number of objects in list
<player info>∗	

<player info> =

4 bytes	object id number
4 bytes	name resource id number
<string>	string associated with name resource

<overlays> =

1 byte	number of overlay bitmaps
<**overlay**>*	

<**overlay**> =

<**resource**>	icon resource of overlay bitmap
<**hotspot**>	hotspot to place overlay on (0 if none; negative to draw under object)
<**animation**>	animation for overlay

<**enchant type**> =

1 byte	1 = player enchantment, 2 = room enchantment

<**bg overlay**> =

<**object**>	object id of overlay
<**resource**>	icon resource of overlay bitmap
<**resource**>	name resource of overlay bitmap
<**animation**>	animation for overlay
<**angle**>	x coordinate of overlay (angle at which to display overlay on background)
2 bytes	y coordinate of overlay (in pixels; 0 = on horizon, positive = up)

<**stat**> =

1 byte	ordinal number of stat within group (starts at 1)
4 bytes	name resource id number
1 byte	type of stat, 1 = numeric stat, 2 = list stat
<**number stat**> or <**list stat**>	

<**number stat**> =

1 byte	type tag for next field; must be 1
4 bytes	current value of stat
4 bytes	minimum value of stat
4 bytes	maximum value of stat
4 bytes	current maximum value of stat

<**list stat**> =

<**object**>	object number to examine when player examines stat
4 bytes	value associated with stat (currently unused)

<**string**> =

2 bytes	length of string
<**length**> bytes	string itself (NOT null terminated)

<**room**> =

4 bytes	room id number

<**resource**> =

4 bytes	resource id number

<**object**> =

4 bytes	object id number

<**group**> =

1 byte	group number (for statistics)

<**coords**> =

2 bytes	row (y position)
2 bytes	column (x position)

<**angle**> =

2 bytes	new angle 0 = east, proceeds clockwise

<**hotspot**> =

1 byte	hotspot number for placement of overlays

<**DLL**> =

<**resource**>	name of DLL file in client's resource directory

<**sector id**> =

2 bytes	sector to animate

<**animation**> =

1 byte	type of animation
2 bytes	bitmap group to display
animate_none	no animation (no extra data)
animate_cycle	cycle through bitmap groups
4 bytes	milliseconds between changing groups
2 bytes	low end of bitmap groups to cycle through
2 bytes	high end of bitmap groups to cycle through (if low = high, cycle through all groups)
animate_once	single-shot animation
4 bytes	milliseconds between changing groups
2 bytes	low end of bitmap groups to cycle through
2 bytes	high end of bitmap groups to cycle through
2 bytes	group to display after this animation is done
animate_translation	special code that indicates the object with this animation info should use a palette translation
1 byte	palette translation type
<**animation**>	actual animation info (can't have aniamte_translation)

Bitmap group numbers start at 1.

<**say type**> =

1 byte	How <**string**> is said:

SAY_NORMAL	Say to everyone in room
SAY_YELL	Yelling
SAY_EVERYONE	Say to everyone logged on
SAY_EMOTE	Show string as player action
SAY_GROUP	Sent to a group of people
SAY_RESOURCE	Resource string “said” by an object

<**printf-param**> =
4 bytes a resource id or integer
or a <**string**>
The interpretation of the value of printf-param depends on the matching field in the format string:

Field in format string	Interpretation of corresponding printf-param
%d or %i	integer
%s	<**resource**>
%q	<**string**>

A.1.3 User command protocol

These are specific commands that apply only to the game of Meridian. Examples include guild commands and chess. All user command messages are sent in the data field of the <**BP_USERCOMMAND**> game mode message, and all message type constants begin with UC.

Messages from the client to the server:

<**UC_REST**>
Rest character.

<**UC_STAND**>
Stand (stop resting).

<**UC_SUICIDE**>
Suicide (destroy character).

<**UC_SAFETY**> <**state**>
Toggle player safety flag (disallows player attacking).
<**state**> =
1 byte 1 = safety on, 0 = safety off

<**UC_REQ_GUILDINFO**>
Ask for guild information.

<**UC_INVITE**> <**object**>

Invite new guild member.

<UC_RENOUNCE>
Renounce guild ties.

<UC_ABDICATE> <object>
Abdicate guildmaster position to another player.

<UC_VOTE> <object>
Vote for guild member.

<UC_SET_RANK> <object> <rank>
Set guild member's rank.
<rank> =

1 byte	Guild member's new rank.

<UC_GUILD_CREATE> <guild name> <rank names> <secret>
Create guild.
<secret> =

1 byte	1 if guild is secret, 0 otherwise

<UC_DISBAND>
Disband guild.

<UC_MAKE_ALLIANCE> <object>
Declare guild as ally.

<UC_END_ALLIANCE> <object>
End alliance with guild.

<UC_MAKE_ENEMY> <object>
Declare guild as enemy.

<UC_END_ENEMY> <object>
End hostilities with guild.

<UC_REQ_GUILD_LIST>
Ask for list of all guilds.

<UC_GUILD_RENT> <object> <password>
Try to rent given guild hall.
<password> =

<string>	Password for guild hall

<UC_ABANDON_GUILD_HALL>

Abandon guild hall.

<**UC_GUILD_PASSWORD**> <**password**>
Change guild hall password.

<**UC_CHANGE_URL**> <**object**> <**string**>
Set URL associated with object.

<**UC_BALANCE**>
Check bank account balance.

<**UC_DEPOSIT**> <**amount**>
Deposit to bank account.
<**amount**> =

4 bytes	amount of money to deposit

<**UC_WITHDRAW**>
Withdraw from bank account.
<**amount**> =

4 bytes	amount of money to withdraw

<**UC_APPEAL**> <**string**>
Appeal to system administrators.

<**UC_REQ_RESCUE**>
Return character to safety.

<**UC_MINIGAME_STATE**> <**object**> <**state**>
State of given minigame object (chess, etc.).
<**state**> =

<**string**>	encoded state of game

<**UC_MINIGAME_RESET_PLAYERS**> <**object**>
Reset players of given minigame.

Messages from the server to the client:

<**UC_GUILDINFO**> <**guild name**> <**password**> <**commands**>
<**guild id**> <**rank names**> <**current vote**> <**userlist**>
Information on player's guild.
<**guild name**> =

<**string**>	name of guild

<**password**> =

1 byte	0 if guild has no password, 1 if it does.

If the guild has a password, it follows:

<**string**>	guild password

<**commands**> =

4 bytes	bitvector of allowed guild commands

<**guild id**> =

<**object**>	object id of guild which player belongs to

<**rank names**> =

<**string**>	male rank 1 name
<**string**>	female rank 1 name
<**string**>	male rank 2 name
<**string**>	female rank 2 name
<**string**>	male rank 3 name
<**string**>	female rank 3 name
<**string**>	male rank 4 name
<**string**>	female rank 4 name
<**string**>	male rank 5 name
<**string**>	female rank 5 name

<**current vote**> =

<**object**>	guild member player is currently supporting

<**userlist**> =

2 bytes	number of players in guild
<**guild user**>*	

<**guild user**> =

<**object**>	member's object id
<**string**>	member's name
1 byte	member's rank (0 = lowest)
1 byte	member's gender (1 = male, 2 = female)

<**UC_GUILD_ASK**> <**cost1**> <**cost2**>
Ask player to set guild creation parameters.
<**cost1**> =

4 bytes	cost of buying non-secret guild

<**cost2**> =

4 bytes	cost of buying secret guild

<**UC_GUILD_LIST**> <**guilds**> <**allied guilds**> <**enemy guilds**>
<**allies**> <**enemies**>
Information on all guilds in the system.

<**guilds**> =

<**guild list**>	list of all guilds

<**allied guilds**> =

<**guild id list**>	list of guilds that are allies of player's guild

<**enemy guilds**> =

<**guild id list**>	list of guilds that are enemies of player's guild

<**guild list**> =

2 bytes	number of guilds
<**guild info**>∗	

<**guild info**> =

<**object**>	object id of guild
<**string**>	name of guild

<**allies**> =

<**guild id list**>	guilds that consider you an ally

<**enemies**> =

<**guild id list**>	guilds that consider you an enemy

<**guild id list**> =

2 bytes	number of guilds
<**object**>∗	

<**UC_GUILD_HALLS**> <**guild hall list**>

List of guild halls available to buy.

<**guild hall list**> =

2 bytes	number of guild halls
<**guild hall**>∗	

<**guild hall**> =

<**object id**>	id of guild hall
<**resource**>	guild hall name
4 bytes	cost of buying guild
4 bytes	daily rent of guild

<**UC_LOOK_PLAYER**> <**object desc**> <**flags**> <**resource**> <**printf-param**>∗ <**resource**> <**printf-param**>∗ <**web string**> <**age**>

Display player's description.

Second resource and printf-param are for player's guild information.

<**web string**> =

<**string**> Web page address of player

<**age**> =
4 bytes player's age in game years

<**UC_SEND_QUIT**>
Leave the game (asks client to send a <**BP_QUIT**>).

<**UC_SPELL_SCHOOLS**> <**num schools**> <**school**>*
Names of spell schools.
<**num schools**> =
1 byte number of spell schools

<**school**> =
<**resource**> name of spell school

<**UC_MINIGAME_START**> <**object**> <**player number**>
Minigame just started (used to send object number to client).
<**player number**> =
1 byte this player's ordinal number among minigame players

<**UC_MINIGAME_MOVE**> <**object1**> <**object2**> <**state**>
Move occurred in minigame (chess, etc.).
<**object1**> minigame object
<**object2**> player who made move

<**state**> =
<**string**> encoded state of game

<**UC_MINIGAME_PLAYER**> <**player number**> <**string**>
Sends name of a player in a minigame (chess, etc.).

```
 * The following is the state string for the only existent minigame, Chess:
 *
 * Board states are communicated to the server via a string.  The encoding works
 * as follows:
 *
 * Each of the first 64 bytes represents one square of the board, in right-to-left,
 * top-down order.  The high order bit is the color of the piece, 0 = white, 1 = black.
 * The low order 3 bits give the piece type:
 * 1 = pawn
 * 2 = rook
 * 3 = knight
 * 4 = bishop
```

```
 * 5 = queen
 * 6 = king
 * 7 = empty square
 *
 * White starts out on the top of the board.
 *
 * The next byte contains:
 * bit 0   always 1
 * bit 1   whose turn it is; 0 = white, 1 = black
 * bit 2   1 if white can castle on the left side
 * bit 3   1 if white can castle on the right side
 * bit 4   1 if black can castle on the left side
 * bit 5   1 if black can castle on the right side
 *
 * The next byte contains:
 * bit 0   always 1
 * bit 1   1 if last move was a pawn move 2 squares forward
 * bit 2-4 row of square which could capture pawn en passant (if bit 1 is 1)
 * bit 5-7 column of square which could capture pawn en passant (if bit 1 is 1)
```

A.2 Server email control protocol

The server can be configured to accept data via the SMTP port. The body of a mail message sent this way can be used to create or delete user accounts. The following mail message body creates a user account:

```
VERSION:1
NAME:username
PASSWORD:password
```

and this message body deletes an account:

```
VERSION:1
NAME:username
```

A.3 Server billing interface protocol

The server can be configured to send TCP/IP messages to an external machine whenever someone logs in or out. This was originally intended to work with the billing system, but it is now unused.

When the server starts up, it attempts to connect to the machine specified in its configuration file (if any). It then sends a STARTUP message over the connection, identifying itself, and waits for a response. When a player logs in, the server sends a LOGIN message, and waits for a respose telling whether the login should be allowed. Finally, when a player logs out, the server sends a LOGOUT message.

Each message is an ASCII string terminated by a newline, with tabs separating fields.

```
STARTUP n
```

where n is the server's number (from its configuration file). The server waits to receive an identical message before allowing any logins.

```
LOGIN username n
```

means the given user is trying to login (n is again the server number). The server waits to receive one of the following messages, indicating whether or not the user should be allowed to login:

```
LOGIN YES username n
LOGIN NO username n
```

```
LOGOUT username n
```

means the given user has logged out.

A.4 Client module interface specification

Modules are Windows DLLs loaded by the client in response to <**BP_LOAD_MODULE**> messages. When the client loads a module, it first calls its `GetModuleInfo` procedure, which has the following prototype:

```
void WINAPI GetModuleInfo(ModuleInfo *info, ClientInfo *client_info)
```

The ModuleInfo structure is filled in by the module to register its interest in client events. The ClientInfo structure contains global state data that the module may need to use. The structures have these formats:

```
typedef struct {
   HANDLE      handle;
   int         event_mask;   // Events for which module wants notifications
   int         priority;     // Order in which modules called; 1 = first
   ID          rsc;          // Resource # of filename, 0 if none
   int         module_id;    // Unique module identifier
} ModuleInfo;
```

The `handle` field is set by the client; it contains the Windows handle of the DLL. Similarly, the `rsc` field gives the resource string identifier of the DLL's filename. All other fields are set by the module.

The `event_mask` indicates which events the module wishes to receive; see below. The client adds each module to a list when the module is loaded. When a module receives an event, it can choose whether it wishes other modules farther down the list to receive the event. The `priority` field specifies the order in which modules are added to the list; the list is kept in order of increasing `priority` field so that a module can choose the order in which it receives or blocks events.

The `module_id` field is an integer unique to each module, used for identification purposes.

A module has access to the following client state:

```
typedef struct {
   HWND         hMain;            // Handle of main window
   Config      *config;
   room_type   *current_room;
   player_info *player;
   HWND        *hCurrentDlg;      // Handle of active modeless dialog
   HINSTANCE    hInst;            // Instance handle of client
   char        *ini_file;         // Name of our private configuration file
   list_type   *current_users;    // List of users currently in game
   HMENU        main_menu;        // Handle of main window menu
   int          platform;         // Operating system (from GetVersionEx)
   Effects     *effects;          // Special effects status
   HPALETTE     hPal;             // Main palette
   HWND         hToolTips;        // Tooltip control
   char        *szAppName;        // Program name
   Bool        *map;              // True when map is being drawn
   Bool        *first_load;       // True when the FIRST module is loaded
   BYTE        (*light_palettes)[NUM_PALETTES][NUM_COLORS];
                                  // Palettes at different light levels
   int         *latency;          // Server latency in milliseconds
} ClientInfo;
```

When the client receives a <**BP_UNLOAD_MODULE**> message, it calls the corresponding module's `ModuleExit` procedure, without actually unmapping the DLL from memory. The module should free its resources and then call back into the client to unmap itself. The `ModuleExit` procedure has the following prototype:

```
void WINAPI ModuleExit(void)
```

A.4.1 Module event types

The following is a description of all the events that modules may receive. A module first registers its interest in an event by specifying the event's id in the `event_mask` field of its `ModuleInfo` strucure, and then receives the event through an exported event handler function. Below we list each event's id, the prototype of its event handler, and a description of the per-event information.

An event handler returns True to allow other modules to receive the event, and False to prevent any further modules from receiving the event.

EVENT_SERVERMSG

```
Bool WINAPI EventServerMessage(char *message, long len)
```

Called when a protocol message arrives from the server; `len` gives the length of the message, which resides in `message`.

EVENT_KEY

```
Bool WINAPI EventKey(HWND hwnd, UINT vk, BOOL fDown,
                     int cRepeat, UINT flags)
```

`hwnd` is the window that received the message; all other fields are as in the Windows WM_KEYDOWN message.

EVENT_USERACTION

```
Bool WINAPI EventUserAction(int action, void *action_data)
```

The user action `action` is about to be performed. `action_data` gives any action-specific data.

EVENT_MOUSECLICK

```
Bool WINAPI EventMouseClick(HWND hwnd, BOOL fDoubleClick,
                            int x, int y, UINT keyFlags)
```

The player clicked a mouse button. The parameters are the same as in the WM_LBUTTONDOWN message.

EVENT_FONTCHANGED

```
Bool WINAPI EventFontChanged(WORD font_id, LOGFONT *font)
```

The player changed the given game font to have the properties specified in `font`.

EVENT_COLORCHANGED

```
Bool WINAPI EventColorChanged(WORD color_id, COLORREF color)
```

The player changed the given game color to the RGB color `color`.

EVENT_MENUITEM

```
Bool WINAPI EventMenuItem(int id)
```

The player selected the given item from a menu.

EVENT_MODULEMSG

```
Bool WINAPI EventModuleMsg(...)
```

This variable argument event type is used for modules to send events to each other. A module may pass in any data it wishes as parameters.

EVENT_STATECHANGED

```
Bool WINAPI EventStateChanged(int old_state, int new_state)
```

The client changed from the `old_state` game state to `new_state`.

EVENT_WINDOWMSG

```
Bool WINAPI EventWindowMsg(HWND hwnd, UINT message, WPARAM wParam,
                           LPARAM lParam)
```

The client's main window loop received the given Windows message. Capturing this message can have serious performance implications, since so many Windows messages arrive.

EVENT_ANIMATE

```
Bool WINAPI EventAnimate(int dt)
```

The client is about to render another frame. `dt` is the number of milliseconds since the previous frame was rendered.

EVENT_TOOLBUTTON

```
Bool WINAPI EventToolbarButton(Button *b)
```

The player clicked on the given toolbar button.

EVENT_TEXTCOMMAND

```
Bool WINAPI EventTextCommand(char *str)
```

The player entered the given text command.

EVENT_RESIZE

`Bool WINAPI EventResize(int xsize, int ysize, AREA *view)`

The main window has been resized to `xsize` by `ysize`. `view` gives the position and size of the client's graphical viewport.

EVENT_USERCHANGED

`Bool WINAPI EventUserChanged(void)`

Some part of the global `player` structure has changed as a result of a server message.

EVENT_REDRAW

`Bool WINAPI EventRedraw(HDC hdc)`

The main window is being entirely redrawn; `hdc` gives the device context to use in redrawing.

EVENT_DRAWITEM

`Bool WINAPI EventDrawItem(HWND hwnd, const DRAWITEMSTRUCT *lpdis)`

The client has received a WM_DRAWITEM message with the given parameters.

EVENT_RESETDATA

`Bool WINAPI EventResetData(void)`

All of the client's game data is stale and needs to be resent by the server.

EVENT_INVENTORY

`Bool WINAPI EventInventory(int command, void *data)`

Something has occurred that affects the player's inventory. The possible values are:

`command`	`data`
INVENTORY_SET	NULL
INVENTORY_ADD	`object_node` of a new object in the inventory
INVENTORY_REMOVE	id number of an object removed from the inventory
INVENTORY_USE	id number of an object newly in use
INVENTORY_UNUSE	id number of an object no longer in use
INVENTORY_CHANGE	id number of an object that changed in the inventory
INVENTORY_USELIST	list of `object_node`s of all objects in use

EVENT_SETCURSOR

`Bool WINAPI EventSetCursor(HCURSOR cursor)`

The client is about to set the cursor for the client window to `cursor`.

EVENT_NEWROOM

`Bool WINAPI EventNewRoom(void)`

The player has entered a new room.

EVENT_SETFOCUS

`Bool WINAPI EventSetFocus(void)`

The client window received the focus.

EVENT_CONFIGCHANGED

`Bool WINAPI EventConfigChanged(void)`

The player changed some configuration settings in the Preferences dialog box.

Appendix B

File formats

All file formats are binary, and all data fields are stored in little-endian byte order, unless otherwise specified. All indices are zero-based, and all sizes and offsets are in bytes unless otherwise specified. To describe a file format, we use the conventions shown in the following example of a table:

Bytes in field	Description of field
4 bytes	number of <**entry**>s (= n)
$4n$ bytes	<**entry**>s
<**entry**> =	
4 bytes	per-entry information
<**entry**>*	zero or more instances of <**entry**>

The file is described in sequential order. A token within angle brackets (`<>`) is a nonterminal symbol that is defined elsewhere in the specification.

B.1 Sound and music files

The client supports music in standard MIDI files. Sounds can be in any of the usual WAV file formats: sampling rates of 11kHz, 22 kHz, 44 kHz, mono or stereo, and 8 bit or 16 bit samples.

B.2 Object code `.bof`

A `bof` file contains the object code generated by compiling a `kod` file with the Blakston compiler. All offsets in the file are relative to the beginning of the file, which is offset 0.

4 bytes	magic number = 42 4F 46 FF (hexadecimal)

4 bytes	version of bof file = 5
4 bytes	offset of source filename
4 bytes	offset of beginning of <**string table**>
4 bytes	offset of beginning of <**debugging info**> (0 if none)
4 bytes	number of classes (= n)
$8n$ bytes	
4 bytes	class id
4 bytes	offset of class in file
<**class**>$*$	
<**string table**>	
<**debugging info**>	
<**string**>	source filename
<**class**> =	
4 bytes	class id of superclass
4 bytes	offset of <**property section**>
4 bytes	offset of <**message section**>
4 bytes	number of class variables for this class and all superclasses
4 bytes	number of default class variable values (= n)
$8n$ bytes	class variable default values
4 bytes	index number of class variable
4 bytes	class variable default <**value**>
<**property section**> =	
4 bytes	number of properties for this class and all superclasses
4 bytes	number of default property values (= n)
$8n$ bytes	property default values
4 bytes	index number of property
4 bytes	property default <**value**>
<**message section**> =	
4 bytes	number of <**message handler**>s (= n)
$12n$ bytes	message handler headers
4 bytes	message id
4 bytes	offset of message handler
4 bytes	index of handler's comment string in <**string table**> (-1 if none)
<**message handler**>$*$	
<**message handler**> =	
1 byte	number of local variables
1 byte	number of parameters (= n)
$8n$ bytes	parameters

4 bytes id of parameter
4 bytes default value of parameter
These parameters must appear in increasing id number order.
<**bkod statement**>∗ Message handler code

<**string table**> =

4 bytes	number of strings (= n)
$4n$ bytes	offset of beginning of each <**string**>

<**string**> =

n bytes	ASCII string characters, null terminated

<**debugging info**> =

4 bytes	number of <**line entry**>s
<**line entry**>∗	

<**line entry**> =

4 bytes	offset in file
4 bytes	corresponding source file line number

<**value**> =
4 bytes

First 4 bits	Type	28 data bits
0000	NIL	all 0
0001	integer	integer value
0010	object	object id
0011	list	list id
0100	string	string id
1100	debugging string	string index into <**debugging info**>

<**bkod statement**> =

1 byte	<**opcode**>
n bytes	data

<**opcode**> =

xxxwyyzz	8 bit opcode value

xxx or *xxxw* specifies the command

000	<**unary assignment**>
001	<**binary assignment**>
010	<**goto**>
011	<**call**>
1001	<**propagate**>
1000	<**return**>

<destination> =

0	local variable
1	property

<source> =

00	local variable
01	property
10	constant
11	class variable

<unary assignment> =

1 byte	opcode
w	**<destination>**
yy	**<source>**
zz	always 00
1 byte	operation
0	logical NOT
1	unary minus
2	no operation
3	bitwise NOT
4 bytes	destination index (property or local variable)
4 bytes	source index (property, local variable, constant, or class variable)

<binary assignment> =

1 byte	opcode
w	**<destination>**
yy	**<source #1>**
zz	**<source #2>**
1 byte	C-like operation
0	+
1	−
2	*
3	/
4	%
5	&&
6	$\vert\vert$
7	=
8	! =
9	$<$
10	$>$
11	$<=$
12	$>=$
13	&
14	$\vert$
4 bytes	destination index (property or local variable)

4 bytes	source #1 index (property, local variable, constant, or class variable)
4 bytes	source #2 index (property, local variable, constant, or class variable)

<**goto**> =

1 byte	opcode
w	<**condition**>
yy	<**source**>
zz	conditional/unconditional jump <**indicator**>
4 bytes	destination address, relative to the beginning of this instruction
4 bytes	source index (not present for unconditional goto)

<**condition**> =

0	jump if source != 0
1	jump if source = 0

<**indicator**> =

0	conditional jump
1	unconditional jump (<**condition**> must be 00)

<**call**> =

1 byte	opcode
wyy	location to store return value
000	local variable
001	property
010	nowhere
1 byte	built-in function to call
4 bytes	destination index for return value (not present if return value not stored)
1 byte	number of <**parameter**>s to the function (= n)
$9n$ bytes	<**parameter**>*

<**parameter**> =

4 bytes	resource identifier of parameter name
1 byte	parameter type
0	local variable
1	property
2	constant
3	class variable
4 bytes	<**value**> of parameter

<**propagate**> =

1 byte	opcode
yy	<**destination**> for return value
4 bytes	destination index for return value

<return> =

1 byte	opcode

B.3 String resource `.rsc`

Compiling a `kod` file also generates a `rsc` file, which contains a mapping of resource identifier numbers to strings. These files are sent to clients, where they are used to decode resource numbers sent in protocol messages. The files are encrypted with the Crusher library to keep users from reading their contents.

4 bytes	magic number = 52 53 43 01 (hexadecimal)
4 bytes	version = 2
4 bytes	number of resources
4 bytes	length of **<encrypted section>**
4 bytes	response to challenge of version number (used in decryption)

<encrypted section>

<encrypted section> =
This section is encrypted with the hexadecimal key xF1x71xC6xBBx19x6Ex2Ex71x6F.
<resource>∗

<resource> =

4 bytes	resource identifier
n bytes	null-terminated string

B.4 Room file `.roo`

A room file contains the BSP tree for a single room. The file can be encrypted to prevent tampering; the client can load both encrypted and unencrypted versions.

Building the BSP tree splits walls into smaller pieces. However, these splits should not appear when the room is later loaded back into the editor. Thus, we store the original walls (before the creation of the BSP tree) in the file separately. The editor loads the original walls and ignores the BSP tree, while the client loads the BSP tree but ignores the original walls.

The editor builds the "server section" of the file so that the server can have some basic knowledge of the room's geometry. Neither the client nor the editor loads this section.

4 bytes	magic number = 52 4F 4F B1 (hexadecimal)
4 bytes	version = 11
4 bytes	**<security>**
4 bytes	offset of **<main info>**
4 bytes	offset of **<server info>**

<**main info**>
<**server info**>

<**main info**> =
<**size**>
<**data**>

<**size**> =

4 bytes	width of room (in client units)
4 bytes	height of room (in client units)

If the width of the room is -1, then the <**data**> section is encrypted.
In this case, these bytes appear here:

4 bytes	length of <**data**>
4 bytes	response to challenge of room security check (used in decryption)

and the <**data**> section is encrypted by the hexadecimal password x15x20x53x01xFCxAAx64.

<**data**> =

4 bytes	offset of <**node subsection**>
4 bytes	offset of <**client wall subsection**>
4 bytes	offset of <**roomedit wall subsection**>
4 bytes	offset of <**sidedef subsection**>
4 bytes	offset of <**sector subsection**>
4 bytes	offset of <**thing subsection**>

<**node subsection**> =

2 bytes	number of <**BSPnode**>s
<**BSP node**>∗	nodes of BSP tree; root must appear first

<**client wall subsection**> =

2 bytes	number of <**client wall**>s
<**client wall**>∗	

<**roomedit wall subsection**> =

2 bytes	number of <**roomedit wall**>s
<**roomedit wall**>∗	

<**sidedef subsection**> =

2 bytes	number of <**sidedef**>s
<**sidedef**>∗	

<**sector subsection**> =

2 bytes	number of <**sector**>s
<**sector**>∗	

<**thing subsection**> =

2 bytes	number of <**thing**>s
<**thing**>∗	

<**BSP node**> =

1 byte	node type
1	internal node
2	leaf node
<**box**>	bounding box of node

<**internal node**> or <**leaf node**>

<**internal node**> =

<**line**>	equation of a line that splits the BSP tree
<**node id**>	BSP node number of + subtree (0 if none, 1 = first wall in file)
<**node id**>	BSP node number of - right subtree (0 if none, 1 = first wall in file)
2 bytes	wall number of first wall in this plane (starts at 1 = first wall in file; 0 if none)

<**leaf node**> =

2 bytes	sector number corresponding to this node (1 = first sector in file)
2 bytes	number of points in polygon defining leaf node
<**point**>∗	points of polygon defining leaf node (clockwise order as seen from above)

<**client wall**> =

2 bytes	next wall in list of walls in plane (0 if none)
2 bytes	sidedef on + side of wall (0 = none, 1 = first sidedef in file)
2 bytes	sidedef on - side of wall (0 = none, 1 = first sidedef in file)
<**point**>	coordinates of start of wall
<**point**>	coordinates of end of wall (positive side is on right going start to end)
2 bytes	length of wall (units: 1 server coordinate unit = length 64)
2 bytes	texture x offset on positive side (in pixels)
2 bytes	texture x offset on negative side (in pixels)
2 bytes	texture y offset on positive side (in pixels)
2 bytes	texture y offset on negative side (in pixels)
2 bytes	sector number on + side of wall (0 = none, 1 = first sector in file)
2 bytes	sector number on - side of wall (0 = none, 1 = first sector in file)

<**line**> =

4 bytes	A in line equation $Ax + By + C = 0$
4 bytes	B in line equation $Ax + By + C = 0$
4 bytes	C in line equation $Ax + By + C = 0$

<**box**> =

point	coordinates of NW corner of bounding box
point	coordinates of SE corner of bounding box

<**point**> =

4 bytes	x coordinate
4 bytes	y coordinate

<**node id**> =
2 bytes

<**sidedef**> =

2 bytes	user-defined id (used for referencing from server)
2 bytes	bitmap number of normal bitmap
2 bytes	bitmap number of above bitmap
2 bytes	bitmap number of below bitmap
<**wall flags**>	various characteristics of the wall
1 byte	animation speed of bitmap on wall, in tenths of a frame per second

<**sector**> =

2 bytes	user-defined id (used for referencing from sector)
2 bytes	bitmap number of floor bitmap
2 bytes	bitmap number of ceiling bitmap
2 bytes	x coordinate of origin of floor and ceiling textures (in pixels)
2 bytes	y coordinate of origin of floor and ceiling textures (in pixels)
2 bytes	floor height (units: size of one server coordinate = 64)
2 bytes	ceiling height (units: size of one server coordinate = 64)
<**light level**>	light level in sector
<**sector flags**>	various characteristics of the sector
1 byte	animation speed of bitmaps in sector, in tenths of a frame per second

if <**sector flags**> indicates a sloped floor, then

<**slope info**>	info on sloped floor

if <**sector flags**> indicates a sloped ceiling, then

<**slope info**>	info on sloped ceiling

<**light level**> =
1 byte

0-127	sector not affected by ambient light; 0 = darkest, 127 = brightest
128-255	sector affected by ambient light; 128 = darkest, 255 = brightest, 192 = neutral

<**roomedit wall**> =

2 bytes	sidedef on + side of wall (0 = none, 1 = first sidedef in file)
2 bytes	sidedef on - side of wall (0 = none, 1 = first sidedef in file)
2 bytes	texture x offset on positive side (in pixels)
2 bytes	texture x offset on negative side (in pixels)
2 bytes	texture y offset on positive side (in pixels)
2 bytes	texture y offset on negative side (in pixels)
2 bytes	sector number on + side of wall
2 bytes	sector number on - side of wall
<**point**>	coordinates of start of wall

<point>	coordinates of end of wall (positive side is on right going start to end)

<thing> =

<point>	location of thing

<wall flags> =

4 bytes

bit 0	1 if bitmaps on wall should be drawn backwards (left-right reversed)
bit 1	1 if normal wall has some transparency
bit 2	1 if objects can pass through wall
bit 3	1 if wall should never be shown on map
bit 4	1 if wall should always be shown on map
bit 5	1 if wall is transparent, but there's nothing behind it
bit 6	1 if upper wall should be drawn bottom up (default is top down)
bit 7	1 if lower wall should be drawn top down (default is bottom up)
bit 8	1 if normal wall should be drawn top down (default is bottom up)
bit 9	1 if wall shouldn't tile vertically (must also be transparent)
bits 10-11	texture scrolling speed, 0 = none, ... 3 = fast
bits 12-14	texture scrolling direction (used only if scroll speed nonzero) 0 = N, 1 = NE, ... 7 = NW

<sector flags> =

4 bytes

bits 0 and 1	"depth" of sector (for wading effects) 0 = no depth, 1 = shallow, 2 = deep, 3 = very deep
bits 2-3	texture scrolling speed, 0 = none, ... 3 = fast
bits 4-6	texture scrolling direction (used only if scroll speed nonzero) 0 = N, 1 = NE, ... 7 = NW
bit 7	1 if floor texture should be scrolled
bit 8	1 if ceiling texture should be scrolled
bit 9	1 if light in sector should flicker
bit 10	1 if sector has a sloped floor
bit 11	1 if sector has a sloped ceiling

<slope info> =

4 bytes	a coefficient in plane equation $ax + by + cz + d = 0$
4 bytes	b coefficient in plane equation $ax + by + cz + d = 0$
4 bytes	c coefficient in plane equation $ax + by + cz + d = 0$
4 bytes	d coefficient in plane equation $ax + by + cz + d = 0$
<point>	texture origin
<angle>	direction of positive u axis (for texture orientation)
2 bytes	vertex number of user-specified sector vertex #1 (used in editor)
2 bytes	z coordinate of vertex #1 (in room editor units)
2 bytes	vertex number of user-specified sector vertex #2 (used in editor)
2 bytes	z coordinate of vertex #2 (in room editor units)

2 bytes	vertex number of user-specified sector vertex #3 (used in editor)
2 bytes	z coordinate of vertex #3 (in room editor units)

<server info> =

4 bytes	number of grid rows (= r)
4 bytes	number of grid cols (= c)
<move grid>	inter-square movement grid
<flag grid>	server square flags

<move grid> =

$r * c$ bytes	one byte for each square in the room, row major order:
bit 0	1 if possible to move to adjacent square to N
bit 1	1 if possible to move to adjacent square to NE
bit 2	1 if possible to move to adjacent square to E
bit 3	1 if possible to move to adjacent square to SE
bit 4	1 if possible to move to adjacent square to S
bit 5	1 if possible to move to adjacent square to SW
bit 6	1 if possible to move to adjacent square to W
bit 7	1 if possible to move to adjacent square to NW

<flag grid> =

$r * c$ bytes	one byte for each square in the room, row major order:
bit 0	1 if square is entirely within playable region (i.e. a real floor covers square)

The <**security**> value is calculated as follows:

1) Calculate the 32 bit signed sum of the following things in the file:

file version number
for each internal node in main section:
  a, b, c coefficients of line
  wall number of first wall in plane
for each leaf node in main section:
  x and y coordinates of each point
for each client wall in client section:
  + and - sidedef numbers
  x and y coordinates of start and end of wall
  + and - sector numbers
for each sidedef in main section:
  user-defined id
  bitmap numbers of normal, above, and below walls
  wall flags value
for each sector in client section:
  user-defined id

bitmap numbers of floor and ceiling
floor and ceiling heights
light level
sector flags value

2) exclusive or with 0x89ab786c

B.5 Graphics `.bgf`

A `.bgf` file contains one or more Windows bitmaps that describe an object, along with information that makes displaying and animating the object easier.

The rows in a bitmap appear in order top to bottom. Each row contains 1 byte per column, left to right. This byte's value is an index into the game's palette.

4 bytes	magic number = 42 47 46 11 (hexadecimal)
4 bytes	version = 9
32 bytes	bitmap name, null terminated
4 bytes	number of <**bitmap**>s
4 bytes	number of <**bitmap group**>s
4 bytes	largest number of bitmaps in any single bitmap group
4 bytes	shrink factor of all bitmaps; divide by this to get size to draw bitmap on screen
<**bitmap**>$*$	
<**bitmap group**>$*$	

<**bitmap group**> =

4 bytes	number of <**bitmap index**>s
<**bitmap index**>$*$	

<**bitmap index**> =

4 bytes	index into bitmaps in file (starts counting from 0)

<**bitmap**> =

4 bytes	width in pixels (= w)
4 bytes	height in pixels (= h)
4 bytes	x offset in pixels
4 bytes	y offset in pixels
1 byte	number of hotspots
<**hotspot**>$*$	hotspot locations
1 byte	format of image, 0 = raw, 1 = compressed

if format = 0

4 bytes	unused (must be 0)
$w * h$ bytes	raw bytes of image

if format = 1	
4 bytes	size of compressed image
$w * h$ bytes	raw bytes of image, compressed by Crusher

<**hotspot**> =

1 byte	hotspot number (unique to this object and all its overlays)
4 bytes	x coordinate
4 bytes	y coordinate

B.6 Map file `.map`

A map file indicates which walls of each room the player has viewed, for use in drawing the map. It also stores map annotations, which are text strings that are associated with locations on a map. These files are kept on client machines.

4 bytes	magic number = 4D 41 50 0F (hexadecimal)
4 bytes	version = 1
<**header table**>	
<**offset table**>$*$	
<**map info**>$*$	

<**header table**> =

<**offset**>	offset of first <**offset table**> for <**digits**> 00; 0 if none
...	
<**offset**>	offset of first <**offset table**> for <**digits**> 99; 0 if none

More <**offset table**>s and <**map info**>s occur interspersed in the file.

<**offset table**> =

<**offset**>	offset of next <**offset table**> in file with same last 2 digits; 0 if none
<**offset table entry**>$*$	100 table entries

<**offset table entry**> =

<**security**>	room security value of a room, 0 if entry is invalid
<**offset**>	offset of <**map info**> for this room

<**map info**> =

4 bytes	number of bits in <**bit table**> = number of walls in room
<**bit table**>	which walls in room are saved as visible
<**offset**>	offset in file of <**annotations**>, 0 if none

<**bit table**> =

An array of bits, 1 bit per wall in the room file, with the first bit corresponding to the first wall. If the bit is 1, the corresponding wall should be shown on the map. The bit table is rounded up in size to the nearest byte.

<**annotations**> =

4 bytes	number of <**map annotation**>s
<**map annotation**>∗	

<**map annotation**> =

4 bytes	x position of annotation (client units)
4 bytes	y position of annotation (client units)
100 bytes	text of annotation, null-terminated

<**offset**> =

4 bytes	offset in bytes from the beginning of the file

<**security**> =

4 bytes	room security value

<**digits**> =

4 bytes	A <**security**> value modulo 100

B.7 Server account file

The account file stores username, password, and administrative information for each account. This is a text file format, one account per line, with fields deilimited by colons.

ACCOUNT <**number**>:<**name**>:<**password**>:<**type**>:<**login time**>:<**credits**>

<**number**> =
Account number; first account is 1.

<**name**> =
String name of account.

<**password**> =
Account password, represented as a sequence of hexadecimal digits, run through the MD5 one-way hash algorithm.

<**type**> =
Type of account.

0	User account
1	Administrator account
2	DM account

3	Guest account

<**login time**> =
Last time the player logged in, in units of seconds since January 1, 1970.

<**credits**> =
Floating point number equal to the number of seconds the player has spent in game mode, divided by 100.

B.8 Saved game format

The server saves its object database in a binary format. When the server next starts, it reads in its last saved game file and initializes its database with these values.

<**class**>*	description of all classes
<**resource**>*	description of all resources
<**system**>	identifies unique system object
<**object**>*	description of all objects
<**list nodes**>	description of all list nodes
<**timer**>*	description of all timers
<**user**>*	description of all users

<**class**> =

1 byte	01 hexadecimal
4 bytes	class identifier
<**string**>	class name
4 bytes	number of properties in class (= n)
<**string**>*	property names

<**resource**> =

1 byte	02 hexadecimal
4 bytes	resource identifier
<**string**>	resource name

<**system**> =

1 byte	03 hexadecimal
4 bytes	object identifier
4 bytes	class identifier for this object
4 bytes	number of properties
<**value**>*	value of each property

<**object**> =

1 byte	04 hexadecimal

4 bytes	resource identifier
<**string**>	resource name

<**list nodes**> =

1 byte	05 hexadecimal
4 bytes	number of list nodes
<**list node**>$*$	values of list nodes

<**list node**> =

<**value**>	value of first part of list node
<**value**>	value of second part of list node

<**timer**> =

1 byte	06 hexadecimal
4 bytes	timer identifier
4 bytes	object that timer will call when it goes off
<**string**>	name of timer
4 bytes	number of milliseconds until timer goes off

<**user**> =

1 byte	07 hexadecimal
4 bytes	user account number
4 bytes	user object identifier

<**string**> =

n bytes	null-terminated ASCII string

<**value**> =

4 bytes	tagged Blakod value (4 bits type, 28 bits value)

Appendix C

Blakod Grammar

The following is a grammar of Blakod. Terminals are enclosed in single quotes.

```
Classes:
                /* empty */
        |       Classes Class

Class:
                Class_Signature Constants_Block Resources_Block Classvars_Block
                Properties_Block Messages_Block end_junk


end_junk:       END
        |       END EOL

Class_Signature:
                id EOL
        |       id 'IS' id EOL

Constants_Block:
                /* empty */
        |       'CONSTANTS' ':' EOL constants_list

Resources_Block:
                /* empty */
        |       'RESOURCES' ':' EOL resource_list

Classvars_Block:
                /* empty */
        |       'CLASSVARS' ':' EOL classvar_list

Properties_Block:
                /* empty */
```

```
        |       'PROPERTIES' ':' EOL property_list

Messages_Block:
                /* empty */
        |       'MESSAGES' ':' message_handler_list

constants_list:
                /* empty */
        |       constants_list constant_assign

constant_assign:
                id '=' expression EOL
        |       'INCLUDE' fname EOL
        |       error EOL

resource_list:
                /* empty */
        |       resource_list resource

resource:
                id '=' resource_const EOL
        |       error EOL

resource_const:
                STRING_CONSTANT
        |       fname

classvar_list:
                /* empty */
        |       classvar_list classvar

property_list:
                /* empty */
        |       property_list property

classvar:
                id '=' expression EOL
        |       id EOL
        |       error EOL

property:
                id '=' expression EOL
        |       id EOL
        |       error EOL
```

```
message_handler_list:
                /* empty */
        |       message_handler_list message_handler

message_handler:
                message_header '{' locals statement_list '}'
        |       message_header STRING_CONSTANT '{' locals statement_list '}'

message_header:
                id parameter_list

locals:
                /* empty */
        |       'LOCAL' vars SEP

vars:
                var
        |       vars ',' var

var:            id

parameter_list:
                '(' ')'
        |       '(' param_list2 ')'

param_list2:
                parameter
        |       param_list2 ',' parameter

parameter:
                id '=' expression

statement_list:
                /* empty */
        |       statement_list statement

statement:
                call SEP
        |       if_stmt
        |       assign_stmt
        |       for_stmt
        |       while_stmt
        |       'PROPAGATE' SEP
        |       'RETURN' expression SEP
        |       'RETURN' SEP
```

```
        |       'BREAK' SEP
        |       'CONTINUE' SEP
        |       error SEP

if_stmt:
                IF expression '{' statement_list '}'
        |       IF expression '{' statement_list '}'
                ELSE '{' statement_list '}'

assign_stmt:
                id '=' expression SEP

for_stmt:
                'FOR' id 'IN' expression '{' start_loop statement_list '}' end_loop

while_stmt:
                'WHILE' expression '{' start_loop statement_list '}' end_loop

start_loop:     /* empty*/

end_loop:       /* empty*/

call:
                id argument_list
        |       '[' ']'
        |       '[' expression_list ']'

expression_list:
                expression
        |       expression_list ',' expression

argument_list:
                '(' ')'
        |       '(' arg_list2   ')'

arg_list2:
                argument
        |       arg_list2 ',' argument

argument:
                expression
        |       '#' id '=' expression

expression:
                expression 'AND' expression
```

```
        |       expression 'OR' expression
        |       expression REL_OP expression
        |       expression '=' expression
        |       expression '+' expression
        |       expression '-' expression
        |       expression '*' expression
        |       expression '/' expression
        |       expression 'MOD' expression
        |       expression '&' expression
        |       expression '|' expression
        |       '-' expression
        |       'NOT' expression
        |       '~' expression
        |       constant
        |       literal
        |       call
        |       id
        |       '(' expression ')'

constant:
                NUMBER
        |       '$'
        |       STRING_CONSTANT

fname:
                FILENAME
        |       IDENTIFIER

literal:
                '&' id
        |       '@' id

id:
                IDENTIFIER

SEP:
                ';'

NUMBER:
                [0-9]+
        |       0x[0-9a-fA-F]+

IDENTIFIER:
                [A-Za-z][A-Za-z0-9_]*
```

```
FILENAME:
                [A-Za-z0-9_\-]*\.[A-Za-z0-9_\-]*

STRING_CONSTANT:
                (([^\"\n\\]|\\.)*\")[ \t\r]*

EOL:
                '\n'

REL_OP:
                '<'
        |       '>'
        |       '<>'
        |       '<='
        |       '>='
        |       '='
```