

OVP VMI Memory Model Component Function Reference

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|---|--------------------------|
| Version: | 6.9.2 |
| Filename: OVP_VMI_Memory_Model_Component_Function_Reference | |
| Project: | OVP VMI MMC Reference |
| Last Saved: | July 28, 2022 |
| Keywords: | MMC |

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1 Introduction

This is reference documentation for version 6.9.2 of the MMC function interface, defined in ImpPublic/include/host/vmi/vmiMmc.h.

The functions in this interface are used to model *memory model components*, such as instruction and data caches, that supplement Imperas processor models.

There are two distinct kinds of memory model component model: *full* and *transparent*. Full models implement storage and so can be used to accurately model components such as caches that are incoherent with main memory. Transparent models do not implement storage (so cannot be incoherent) but can be used to create very fast performance monitors. As an example, a transparent cache model would model only the cache tags and use this information to count hits and misses.

Functions in this interface have the prefix vmimme.

1.1 Transparent and Full MMC models

MMCs operate in two modes:

In Full Mode the model must implement read and write requests delivered to it. Transactions can be satisfied locally (to simulate a cache-hit for example) or routed to other models (to simulate a cache-miss). Since the model is simulating the storage and recovery of data, cache coherency can be modeled in this mode.

Full mode has a detrimental effect on simulator performance especially when used with very high speed processor models.

In Transparent Mode, the simulator automatically routes the read and write requests around the model to whatever is connected beyond it. The model is notified of every access by a callback function. The function is used to record data but does not implement the reads and writes. Since data is not read or written by the model (other than for performance analysis), cache coherency cannot be modeled in this mode, so cache behavior will appear full coherent.

Transparent Mode has less effect on simulation performance.

The simulator chooses the mode of operation. It is recommended that both full and transparent modes are implemented so that a model can be used in both cases.

2 Example

A simple module that uses an MMC to model a cache is in

\$IMPERAS_HOME/Examples/PlatformConstruction/fullMMC.

The module uses an OVP model from

\$IMPERAS_HOME/ImperasLib/source/ovpworld.org/mmc/wb_1way_32byteline_2048tags/1.0

The source of this model is in

\$IMPERAS_HOME/ImperasLib/source/ovpworld.org/mmc/support/1.0/include/cache.h

Note: Run-time tests in MMCs that would be required if the model were written to have its configuration specified at run time would significantly affect the performance of the model. Therefore this include file is parameterized to construct separate cache models that are configured at compile time, thus saving the overhead of configuration computations at run time.

2.1 Model attributes table

An MMC model defines a table that contains the addresses of entry functions required by the simulator. The table is defined by the type <code>vmimmcAttrs in vmimmcAttrs.h</code> and must be called <code>modelattrs</code>.

```
vmimmcAttr modelAttrs = {
    .versionString = VMI_VERSION,
    modelType = VMI_MMC_MODEL,
    .componentSize = sizeof(cacheObject),
    .constructorCB = cacheConstructor,
    linkCB = cacheLink,
    .destructorCB = cacheDestructor,
    .refreshCB = cacheRefresh,
    .readNFullCB = readNFull,
    .writeNFullCB = readNTransparent,
    .writeNTransparentCB = readNTransparent,
    .writeNTransparentCB = paramSpecs,
    .paramSpecsCB = paramSpecs,
    .paramValueSizeCB = nextBusPortSpec
};
```

The fields must be initialized as follows:

2.2 Construction and specification

.versionString

Must be set to the macro VMI_VERSION defined in vmiVersion.h

.modelType

Must be set to VMI_MMC_MODEL defined in vmiTypes.h

.componentSize

Must be set to the total size (in bytes) of the data object defined by your model. In the example cache.h, data is stored in the structure cacheObject.

.constructorCB

Use the macro VMIMMC_CONSTRUCTOR_FN to define your constructor function. This is used to construct and initialize data associated with the MMC instance.

.destructorCB

Use the macro VMIMMC_DESTRUCTOR_FN to define your destructor function. This is used to free any resources allocated by your model, and to report statistics and other information to the use at the end of simulation.

.linkCB

This function is used when this is a transparent cache, to link to another cascaded cache.

.paramSpecsCB

This function is used by the simulator to get a list of formal parameters read by this model. Parameters are set in the platform and can be read by the model to change its behavior. Parameter usage is described in more detail in the next section.

.paramValueSizeCB

This function is used by the simulator to get the size of a parameter block needed to hold parameters for the MMC model. Parameter usage is described in more detail in the next section.

.busPortSpecsCB

This function is used by the simulator to get a list of bus ports used by the model.

2.3 Refresh

.refreshCB

This function is called before an MMC model becomes active (with state RS_RUN) and before an MMC model becomes inactive (with state RS_SUSPEND). The purpose of the callback is to allow the MMC model to update its state to take account of changes in the platform while it has been inactive (if RS_RUN) or to propagate state changes from the model to the wider platform (if RS_SUSPEND).

2.4 Read and Write callbacks – full MMC mode

.readNFullCB

This function is called to implement the reading of data by the bus master connected to this model. It can supply the data from a local source or might choose to read data from another source via its bus slave port.

.writeNFullCB

This function is called to implement the writing of data by the bus master. It can store the data locally or might choose to write it to another destination via a master port.

2.5 Read and Write callbacks – transparent MMC mode

.readNTransparentCB

.writeNTransparentCB

These functions do not implement the read and write callbacks – the simulator reads and writes data automatically from whatever is connected to the model's slave ports. Instead these called are used to record whatever information is required by the transparent model.

3 Model Configuration

A model can have optional features that can be configured by the platform during construction. Configuration is controlled by parameters which form part of the model's interface.

3.1 Model Parameters

Parameters are specified to the simulator by an iterator function and a size function specified in the model's attributes table. A parameter specification specifies the data type and bounding conditions of the parameter so the model does not need to check for trivial errors. The model must define a structure which contains value fields for each parameter. It should use the provided macros of the form VMI_<type>_PARAM, which reserve space for the value and for a Boolean which is true if the parameter has been set by the platform, false otherwise.

| macro | data type |
|------------------|---------------------|
| VMI_BOOL_PARAM | boolean |
| VMI_INT32_PARAM | 32 bit signed |
| VMI_INT64_PARAM | 64 bit signed |
| VMI_UNS32_PARAM | 32 bit unsigned |
| VMI_UNS64_PARAM | 64 bit unsigned |
| VMI_DBL_PARAM | floating point |
| VMI_STRING_PARAM | 0 terminated string |
| VMI_ENUM_PARAM | 0 terminated string |
| VMI_ENDIAN_PARAM | 0 terminated string |
| VMI_PTR_PARAM | native host pointer |

The supported parameter types are described below:

During initialization, the simulator uses the iterator function to get the list of parameters for the model. Then it allocates the model's parameter structure (using the size function) and fills in the correct values. This structure is then passed to the model's constructor where the model can use the values.

3.2 Parameter Specification

The parameter specification structure is defined in vmiParameters.h and should be initialized using these macros:

| macro | data type | limits |
|-----------------------|---------------------|------------------------------------|
| VMI_BOOL_PARAM_SPEC | boolean | 0 or 1 |
| VMI_INT32_PARAM_SPEC | 32 bit signed | specified min / max |
| VMI_INT64_PARAM_SPEC | 64 bit signed | specified min / max |
| VMI_UNS32_PARAM_SPEC | 32 bit unsigned | specified min / max |
| VMI_UNS64_PARAM_SPEC | 64 bit unsigned | specified min / max |
| VMI_DBL_PARAM_SPEC | floating point | specified min / max |
| VMI_STRING_PARAM_SPEC | 0 terminated string | any string (or 0 if not specified) |

| VMI_ENUM_PARAM_SPEC | 0 terminated string | string must be a member of the specified list |
|-----------------------|---------------------|---|
| VMI_ENDIAN_PARAM_SPEC | 0 terminated string | "big" or "little" |
| VMI_PTR_PARAM_SPEC | native host pointer | none |

The iterator function must be supplied by the model and should use the provided macro from vmiMmcAttrs.h:

Prototype

```
#define VMIMMC_PARAM_SPECS_FN(_NAME) vmiParameterP_NAME ( \
    vmimmcComponentP component, \
    vmiParameterP prev \
)
```

It should return the first or subsequent parameter specification or 0 if at the end of the list. Note that the iterator is also supplied with the MMC component pointer, so can include or exclude parameters in an instance-specific way if required.

Example

```
// VMI header files
#include "vmi/vmiMmcAttrs.h"
#include "vmi/vmParameters.h"
// Define the parameter structure
11
typedef struct paramValuesS {
    VMI_BOOL_PARAM(verbose); // boolean parameter
VMI_UNS32_PARAM(numSlavePorts); // 32 bit unsigned parameter
} pVals, *pValsP;
11
// Define the parameters
11
static vmiParameter formals[] = {
                                                              "Enable text output"),
    VMI_BOOL_PARAM_SPEC( pVals, verbose,
                                               Ο,
    VMI_UNS32_PARAM_SPEC( pVals, numSlavePorts, 1, 1, 8, "Slave port number"),
    // Add entry with name==NULL to terminate list
    VMI END PARAM
};
1
// Function to iterate the parameter specs
11
VMI PROC PARAM_SPECS_FN(getParamSpec) {
    if(!prev) {
        return formals;
    } else {
        prev++;
        if (prev->name)
            return prev;
        else
            return 0;
    }
}
// Get the size of the parameter values table
11
VMI PROC PARAM TABLE SIZE FN (paramValueSize) {
    return sizeof(pVals);
```

```
}
11
// model constructor
//
VMIMMC CONSTRUCTOR FN(modelConstructor) {
    myMMCP myMMC = (myMMCP) component;
    pValsP params = (pValsP)parameterValues; // cast to my type
    // use the parameter values
    myMMC->numSlavePorts = params->numSlavePorts;
    if (params->verbose) {
       vmiPrintf(....);
    }
    . . .
}
11
// Add functions to the model attributes table
11
const vmiMMCAttr modelAttrs = {
    . . .
    .constructorCB = modelConstructor,
.paramSpecsCB = getParamSpec,
    .paramValueSizeCB = paramValueSize,
    • • •
};
```

Restrictions

The parameter structure exists only for the life of the constructor function.

4 Functions

4.1 vmimmcGetName

Prototype

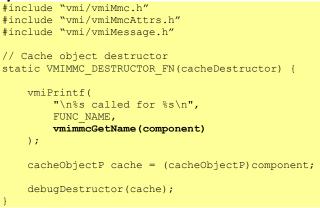
const char *vmimmcGetName(vmimmcComponentP component);

Description

This function returns the name of an MMC component. Typically this will be used in debug messages or in summary messages.

The name returned is that of the component only, as defined in the platform file. The related function <code>vmimmcGetHierarchicalName</code> returns the name including the full instantiation path.

Example



Notes and Restrictions

None.

4.2 vmimmcGetHierarchicalName

Prototype

const char *vmimmcGetHierarchicalName(vmimmcComponentP component);

Description

This function returns the name of a memory model component, including the full instantiation path, as defined in the platform file.

The related function vmimmcGetName returns the component base name omitting the instantiation path.

Example

```
#include "vmi/vmiMmc.h"
#include "vmi/vmiMmcAttrs.h"
#include "vmi/vmiMessage.h"
// Cache object destructor
static VMIMMC_DESTRUCTOR_FN(cacheDestructor) {
    vmiPrintf(
        "\n%s called for %s\n",
        FUNC_NAME,
        vmimmcGetHierarchicalName(component)
    );
    cacheObjectP cache = (cacheObjectP)component;
    debugDestructor(cache);
}
```

Notes and Restrictions

None.

4.3 vmimmcGetNextPort

Prototype

```
vmimmcPortP vmimmcGetNextPort(
    vmimmcComponentP component,
    const char *portName
);
```

Description

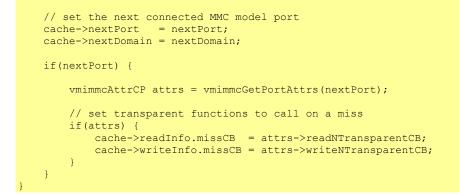
Given an MMC component and an output port name for that component, this function returns the input port of any subsequent MMC component connected to that port.

Typically, this is used in combination with <code>vmimmcGetPortAttrs</code> to establish connectivity in the <code>VMIMMC LINK FN</code> callback, as shown in the following example.

This function returns non-NULL only if the current MMC component is *transparent*. If the component implements a full MMC model, this function will return NULL, but <code>vmimmcGetNextDomain</code> will return the connected domain.

Example

```
// Cache object
typedef struct cacheObjectS {
    vmimmcPortP nextPort; // next port (TRANSPARENT;
memDomainP nextDomain; // next domain (FULL)
memRegionP lastRegion; // last accessed (FULL)
Addr mruKey; // access optimization
cacheLineP mruLine; // access optimization
cacheAccessInfo readInfo; // read access recording
cacheAccessInfo writeInfo; // write access recording
                                                                      // MODELING ARTIFACTS
                                                                     // next port (TRANSPARENT)
                   // TRUE CACHE CONTENTS
keys[CACHE_TAGS][CACHE_WAYS]; // set of keys for cache
     Addr
     cacheLineP index [CACHE TAGS] [CACHE WAYS]; // index into cache lines
     cacheLine lines[CACHE TAGS][CACHE WAYS]; // set of lines for cache
} cacheObject, *cacheObjectP;
// Cache object link
static VMIMMC LINK FN(cacheLink) {
     vmiPrintf(
           "\n%s called for %s\n",
           FUNC NAME,
           vmimmcGetHierarchicalName(component)
     );
     cacheObjectP cache = (cacheObjectP)component;
vmimmcPortP nextPort = vmimmcGetNextPort(component, "mpl");
memDomainP nextDomain = vmimmcGetNextDomain(component, "mpl");
     // sanity check that we know whether we are in transparent or full
     // mode
     VMI ASSERT(
           ! (nextPort && nextDomain),
           "%s: expected either nextPort (transparent) "
           "or nextDomain (full), not both",
           FUNC NAME
     );
```



Notes and Restrictions

None.

4.4 vmimmcGetNextDomain

Prototype

```
memDomainP vmimmcGetNextDomain(
    vmimmcComponentP component,
    const char *portName
);
```

Description

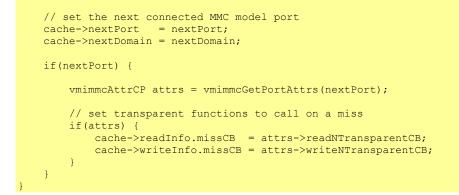
Given an MMC component and an output port name for that component, this function returns any memory domain object connected to that port.

This function returns NULL if the current MMC component is *transparent*. In this case, vmimmcGetNextPort should be used to obtain information about the next port.

The domain is typically used in full model callback functions. As an example, a model of a cache may need to call vmirtReadNByteDomain or vmirtWriteNByteDomain in the case of a cache miss.

Example

```
// Cache object
    >def struct cached
vmimmcPortP nextPort; // next domain (FOLD,
memDomainP nextDomain; // next domain (FOLD,
memRegionP lastRegion; // last accessed (FULL)
Addr mruKey; // access optimization
cacheLineP mruLine; // access optimization
cacheAccessInfo readInfo; // read access recording
cacheAccessInfo readInfo; // write access recording
typedef struct cacheObjectS {
                     keys[CACHE TAGS][CACHE_WAYS]; // set of keys for cache
     Addr
      cacheLineP index[CACHE TAGS][CACHE WAYS]; // index into cache lines
      cacheLine lines[CACHE TAGS][CACHE WAYS]; // set of lines for cache
} cacheObject, *cacheObjectP;
// Cache object link
static VMIMMC LINK FN(cacheLink) {
      vmiPrintf(
             "\n%s called for %s\n",
            FUNC NAME,
            vmimmcGetHierarchicalName(component)
      );
     cacheObjectP cache = (cacheObjectP)component;
vmimmcPortP nextPort = vmimmcGetNextPort(component, "mp1");
      memDomainP nextDomain = vmimmcGetNextDomain(component, "mp1");
      // sanity check that we know whether we are in transparent or full
      // mode
      VMI ASSERT(
             ! (nextPort && nextDomain),
             "%s: expected either nextPort (transparent) "
            "or nextDomain (full), not both",
            FUNC NAME
      );
```



Notes and Restrictions

None.

4.5 vmimmcGetPortAttrs

Prototype

vmimmcAttrCP vmimmcGetPortAttrs(vmimmcPortP port);

Description

Given an MMC input port, this function returns the attribute structure associated with that port. The attribute structure defines the behavior of the input port (for example, callback functions to be activated when data is read or written).

Typically, this is used in combination with <code>vmimmcGetNextPort</code> to establish connectivity in the <code>VMIMMC_LINK_FN</code> callback, as shown in the following example.

Example

```
// Cache object
typedef struct cacheObjectS {
                                                                      // MODELING ARTIFACTS
    vmimmcPortP nextPort;
memDomainP nextDomain;
memRegionP lastRegion;
Addr mruKey;
cacheLineP mruLine;
                                                                      // next port (TRANSPARENT)
                                                          // next port (TRANSPARENT)
// next domain (FULL)
// last accessed (FULL)
// access optimization
// access optimization
// read access recording
// write access recording
     cacheAccessInfo readInfo;
     cacheAccessInfo writeInfo;
     Addr keys[CACHE_TAGS][CACHE_WAYS]; // TRUE CACHE CONTENTS
cacheLineP index[CACHE_TAGS][CACHE_WAYS]; // index into cache lines
cacheLine lines[CACHE_TAGS][CACHE_WAYS]; // set of lines for cache
} cacheObject, *cacheObjectP;
// Cache object link
static VMIMMC LINK FN(cacheLink) {
     vmiPrintf(
           "\n%s called for %s\n",
           FUNC NAME,
           vmimmcGetHierarchicalName(component)
     );
     cacheObjectP cache = (cacheObjectP)component;
vmimmcPortP nextPort = vmimmcGetNextPort(component, "mp1");
memDomainP nextDomain = vmimmcGetNextDomain(component, "mp1");
     // sanity check that we know whether we are in transparent or full
     // mode
     VMI ASSERT(
           ! (nextPort && nextDomain),
           "%s: expected either nextPort (transparent) "
           "or nextDomain (full), not both",
           FUNC NAME
     );
     // set the next connected MMC model port
     cache->nextPort = nextPort;
     cache->nextDomain = nextDomain;
     if(nextPort) {
           vmimmcAttrCP attrs = vmimmcGetPortAttrs(nextPort);
```

```
// set transparent functions to call on a miss
if(attrs) {
    cache->readInfo.missCB = attrs->readNTransparentCB;
    cache->writeInfo.missCB = attrs->writeNTransparentCB;
}
```

Notes and Restrictions

None.

}

4.6 vmimmcRefreshTransparent

Prototype

```
vmimmcAttrCP vmimmcRefreshTransparent(
    vmimmcPortP    port,
    vmiIASRunState state
);
```

Description

When an MMC's refresh callback is called, the model must refresh any cascaded MMCs.

Typically, this is used in combination with vmimmcRefreshFull so that either transparent or full models are refreshed.

Example

```
// Cache refresh callback
static VMIMMC REFRESH FN(cacheRefresh) {
    // get cascaded models (which must be held on the model object).
   cacheObjectP cache = (cacheObjectP)component;
vmimmcPortP nextPort = cache->nextPort;
memDomainP nextDomain = cache->nextDomain;
    if(nextPort) {
        vmimmcRefreshTransparent(nextPort, state);
    else if (nextDomain) {
        vmimmcRefreshFull(nextDomain, state);
    } else {
        // there are no cascaded components
    }
    // now perform local refresh actions.
vmimmcAttr modelAttrs = {
    cacheDestructor,
    cacheRefresh, // install the refresh callback
    readNFull,
    . . .
};
```

Notes and Restrictions

The refresh callback is updated at the start of each time-slice. It is typically used in a full cache model to synchronize its state with any changes to the memory it is caching that were caused by other processors.

4.7 vmimmcRefreshFull

Prototype

```
vmimmcAttrCP vmimmcRefreshFull(
    vmimmcPortP port,
    memDomainP nextDomain
);
```

Description

When an MMC's refresh callback is called, the model must refresh any cascaded MMCs.

Typically, this is used in combination with vmimmcRefreshTransparent so that either transparent or full models are refreshed.

Example

```
// Cache refresh callback
static VMIMMC REFRESH FN(cacheRefresh) {
    // get cascaded models (which must be held on the model object).
   cacheObjectP cache = (cacheObjectP)component;
vmimmcPortP nextPort = cache->nextPort;
memDomainP nextDomain = cache->nextDomain;
    if(nextPort) {
        vmimmcRefreshTransparent(nextPort, state);
    else if (nextDomain) {
        vmimmcRefreshFull(nextDomain, state);
    } else {
        // there are no cascaded components
    }
    // now perform local refresh actions.
vmimmcAttr modelAttrs = {
    cacheDestructor,
    cacheRefresh, // install the refresh callback
    readNFull,
    . . .
};
```

Notes and Restrictions

The refresh callback is updated at the start of each time-slice. It is typically used in a full cache model to synchronize its state with any changes to the memory it is caching that were caused by other processors.

4.8 vmimmcAddCommand

Prototype

```
void vmimmcAddCommand(
   vmimmcComponentP component,
   const char *name,
   const char *exampleArguments,
   vmimmcCommandFn commandCB
);
```

Description

This function adds a command that can be called from the simulator. The command is typically used to change the mode of the MMC or to report something about its internal state.

Please use *vmimmcAddCommandParse* in preference to this function.

Example

```
static VMIMMC COMMAND FN(enableCallback) {
   if (argc == 2) {
       const char *firstArg = argv[1];
       ... // use the argument
       return "OK";
   } else {
       vmiPrintf("Error calling command '%s'", argv[0]);
       return "";
   }
// Cache constructor callback
static VMIMMC REFRESH FN(cacheconstructor) {
   vmimmcAddCommand(
       component,
       "enable",
       "-on | -off" // this is used by the help system
       enableCallback
   );
```

Notes and Restrictions

The string returned by the command callback is passed to the tcl interpreter (if an interpreter is active).

4.9 vmimmcAddCommandParse

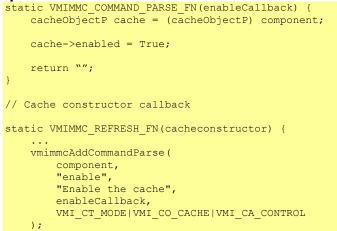
Prototype

```
void vmimmcAddCommandParse(
   vmimmcComponentP component,
   const char *name,
   const char* help,
   vmimmcCommandParseFn commandCB,
   vmiCommandAttrs attrs
);
```

Description

This function adds a command that can be called from the simulator. The command is typically used to change the mode of the MMC or to report something about its internal state.

Example



Notes and Restrictions

The string returned by the command callback is passed to the tcl interpreter (if an interpreter is active).

5 Model Design Considerations

This section is intended to provide some Questions and Answer that may aid in the efficient design and use of the MMC as a modeling component.

5.1 What is the difference between Transparent and Full

In transparent mode the data transfers are not modified, the MMC is called back to say what has happened but transfers are direct between processor and other models and memory i.e. there is no change.

In full mode the MMC is providing cached data/instructions, it is the responsibility of the cache model to correctly fill and provide the data to the processor model. Any errors in the coding of the cache model could cause issues with program execution.

5.2 What limitations are there using an MMC for cache modeling

When using an MMC as a cache model you do not get the action of the cache instructions, such as flush etc, applied to the cache memory. This can also have an effect on the program execution depending how the application code is written.