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**SYMBOLIC COMPUTATION SOFTWARE COMPOSABILITY
PROTOCOL (SCSCP) SPECIFICATION
VERSION 1.2**

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CONTENTS

1. INTRODUCTION

This document specifies the requirements for the software to be developed by the NA3 activity of the SCIEnce project for the subsequent usage in the NA3 and JRA1 activities.

Specifically it describes a protocol by which a CAS may offer services and a client may employ them. This protocol is called the *Symbolic Computation Software Composability Protocol*, or **SCSCP**. We envisage clients for this protocol including:

- A Web server which passes on the same services as Web services using SOAP/HTTP to a variety of possible clients;
- Grid middleware;
- Another instance of the same CAS (in a parallel computing context);
- Another CAS running on the same system.

Note that the specification assumes two possible ways of implementation. One is the standard socket-based implementation, where a CAS can talk locally or remotely via ports, as described in the section 5, in fact an SCSCP service rather then a Web service. The other implementation is a proper Web service using standard SOAP/HTTP wrappings for SCSCP messages. In the SCSCP specification we will use the term *Web services* in the broad sense, meaning both kinds of symbolic computation services.

Our vision of the SCSCP usage is described on the following scheme.
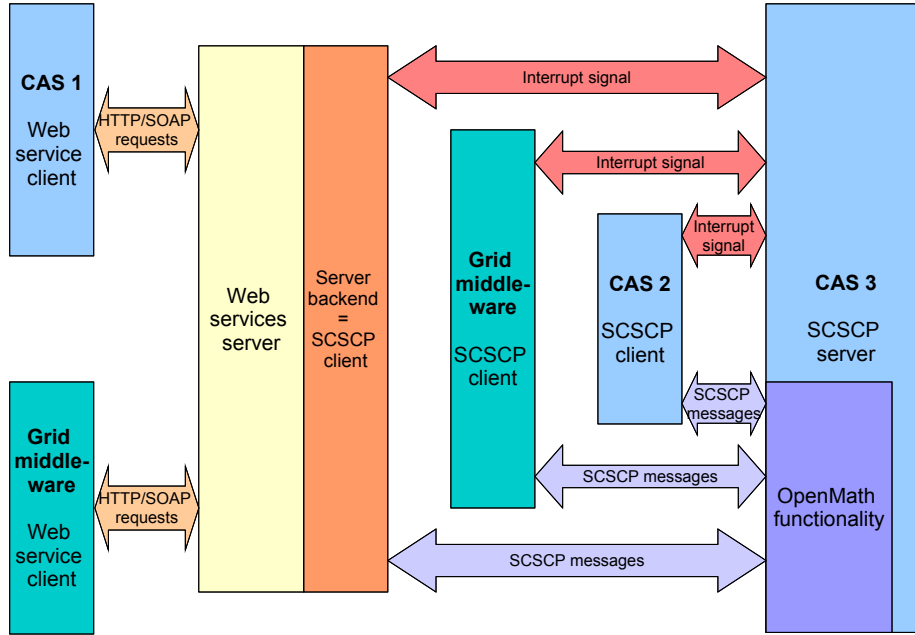
Figure 1. SCSCP usage.

In Section 2 we describe the meaning of all possible messages that can appear during communication between various software and the allowed sequences of such messages. In Section 4 we specify how these messages are encoded as OpenMath objects. Finally in Section 5 we describe one solution (suitable for UNIX systems, at least) for the practical problems of establishing a connection and delivering these messages.

In Appendix A we specify the list of necessary OpenMath symbols. Examples of OpenMath messages are given in Appendix B.

List of abbreviations used in the document:

CAS: Computer Algebra System
CD: Content Dictionary
OM: OpenMath
PI: processing instruction (in XML)
SCSCP: Symbolic Computation Software Composability Protocol
WS: Web Service
WSDL: Web Services Description Language

2. Semantic descriptions

2.1. **Messages to CAS.**

2.1.1. *Procedure call.* This is an OM message containing the following information:
- *Procedure name* - the name of the procedure registered as a web-service;
- *Arguments* - arguments that will be passed to the procedure being called; (Remark: we treat procedure options, i.e. guidance options for used algorithms, as arguments as well);
- *Options/Attributes* - attributes and options that will specify the behaviour of the system:
    - call identifier;
    - type of action performed with the result:
        * storing the result at the CAS side and returning a cookie referring to it;
        * returning the result of the procedure (that may involve actual computation or retrieving previously stored result);
        * not responding to the client;
    - procedure runtime limit;
    - minimal/maximal memory limits;
    - debugging level, determining degree of output detail;
    - other options that might appear during the development; may be system dependent.

There are some standard procedures pre-defined in Section 3. Besides this, in order to provide specific SCSCP services, the service provider should develop and make available own customized procedures, which may range from generic services (e.g. we may imagine some procedure named like EVALUATE_OMOBJ to evaluate given OM object) to specific (e.g. compute the determinant of a matrix).

2.1.2. *Interrupt signal.* This signal can be sent to the CAS at any time, and should be processed "out-of-band". That is, it should be processed as soon as possible, and not wait behind other messages that may have been sent or received before it and are unprocessed.

This message implies that the results of the computation currently being performed are not needed,so the CAS need not complete the computation. If the CAS chooses not to complete the calculation it should send a *Procedure terminated* message reporting this.

There are some obvious and undesirable race conditions associated with this message, since the computation being performed when it is received may not be the one the client expects to be being performed. Ideally the solution would be for this message to carry the identity of the procedure call to be interrupted, but it is

significantly easier to deliver an out-of-band message with no content than one with content, so, for the time being, we ignore this problem. The client can, at least, detect when this has happened by watching the message stream from the CAS.

Note that it is always correct for a CAS to ignore an interrupt, and that this may be appropriate when procedure calls are quick. It is assumed that this option will be regulated by the WS provider.

2.2. **Messages from CAS.**

2.2.1. *Procedure completed.* This is an OM message containing the information about the result of the procedure:

- *Result value* - if the procedure returns result, it must be contained in this section of the message. If the procedure only produces side-effect, such section is not necessary, since this message itself acts as a signal about its successful completion;
- *Additional information*
    - call identifier;
    - procedure runtime;
    - memory used;
    - other information that we might need (may be system dependent).

2.2.2. *Procedure terminated.* This is an OM message that acts as a signal about procedure termination. It must contain the following debugging information:

- if termination was caused by the CAS, then it must carry the original message from the CAS running as a WS;
- if termination was caused by another standard error, then it must carry the description of this error, in particular:
    - can not compute OM object;
    - invalid cookie (the object does not exist);
    - terminated by interrupt;
    - procedure not supported;
    - ran out of resource (time or memory);
- call identifier;
- procedure runtime before termination;
- memory used (if available);
- other information that we might need (may be system dependent).

2.3. **Allowed sequences of messages.** Once a connection has been established and any initial technical information exchanged (the mechanism for which is part of an implementation of this protocol and addressed in section 5) the SCSCP session is considered to be opened.

Until the end of the session, the communication from client to CAS is a stream of procedure calls and the response is a stream of procedure completed and/or procedure terminated messages. The client is permitted to send as many procedure calls as it likes, subject to the buffering capabilities of the channel used in a particular implementation. The CAS must process them in sequence and send *either* a procedure completed, *or* a procedure terminated message (but not both) for each. As a convenience and to assist debugging, the calls and responses are also associated via the `call_ID` attribute.

Apart from this, the client can send an interrupt message to the CAS. The interrupt message can be sent to the CAS at any time and should be delivered and acted on immediately. It entitles the CAS to stop processing the current procedure call and respond to it with a suitable procedure terminated message.

3. SPECIAL PROCEDURES

This section documents certain predefined procedures which every compliant client is expected to support. OpenMath symbols corresponding to these procedures are defined in the `scscp2` Content Dictionary [2].

3.1. **Determining the list of supported procedures.**

3.1.1. *Representing Collections of OpenMath Symbols.* A number of the procedures defined in this section return values which are intended to represent sets of OM symbols. For convenience, we define a standard way of representing these sets.

Such sets should be represented as applications of the symbol `symbol_set` which may take any number of arguments. Each of those arguments should be one of three things:

(1) An OpenMath symbol, representing itself
(2) An application of one of symbols `CDName` or `CDURL` from the `meta` CD, representing all the symbols in the referenced CD.
(3) An application of one of the symbols `CDGroupName` or `CDGroupURL` from the `metagrp` CD, representing all the symbols in all CDs in the referenced CD group.

As an alternative, the symbol `symbol_set_all` can be used, to represent the set of all OpenMath symbols from any CD.

3.1.2. *Transient CDs.* In describing its allowed procedure calls according to the conventions of this section, a server is permitted to refer to symbols from CDs with names beginning `SCSCP_transient_`. These are content dictionaries defined by this server, and valid only for the duration of the session. If needed, the client can request these CDs using the `get_transient_cd` procedure (see below).

3.1.3. *Requesting the Allowed Procedure Names.* The first standard procedure defined in this section is `get_allowed_heads`, which takes no arguments. This returns, in the above format, the set of OpenMath symbols which might be allowed to appear as "head" symbol (ie first child of the outermost `<OMA>`) in an SCSCP procedure call to this server. These may be symbols from standard OpenMath CDs or from transient CDs as described above. Note that it is acceptable (although not necessarily desirable) for a server to "overstate" the set of symbols it accepts and use standard OpenMath errors to reject requests later.

3.1.4. *Requesting Signature Information.* The standard procedure `get_signature` takes one argument – an OpenMath symbol. If the supplied symbol is one of those accepted as a head symbol by the server then it returns an application of the `signature` symbol. This symbol takes four arguments:

- an OpenMath symbol which signature is described;
- a minimum number of children (*min*);
- a maximum number of children (*max*), which can be the `infinity` symbol from the `nums1`);

- a set of symbols, represented as an application of the symbol `symbol_set`, or a list of `symbol_set`s:
  - if the list of `symbol_set`s is given, than its i-th entry corresponds to the i-th child;
  - if just one `symbol_set` is given, it is interpreted as meaning that the symbol may be meaningfully used as a procedure call with between *min* and *max* arguments (inclusive) and that the symbols in the set may form part of acceptable values for the arguments.

3.1.5. *Requesting Transient CDs.* The standard procedure `get_transient_cd` takes one argument – an application of the `CDName` symbol from `meta`, which should begin `SCSCP_transient_` and returns the corresponding CD, encoded using symbols from the `meta` CD. If no such transient CD is defined by this server it returns the `procedure_terminated` message with OM error containing the symbol `no_such_transient_cd` and the name of the CD that caused the problem.

3.1.6. *Requesting general description of the service.* The service provider may have various parameters describing an offered service. The connection initiation message contains only service name, version and identifier, and this is not enough. Instead of this, some meta-information about the service may be structured and retrieved by a special standard procedure `get_service_description`. It takes no arguments, since it is completely determined by the server to which it was sent, and returns the symbol `service_description` that takes the following three arguments as OM strings: CAS name, CAS version and the description of the service: e.g. functions exposed, resources, contact details of service provider, etc.

3.2. **Operations with remote objects.**

3.2.1. *Storing, retrieving and deleting remote objects.* The following symbols are defined in the `scscp2` CD [2] to work with remote objects:

    `store:` compute an object on the server side and store it there, returning only a cookie (actually, an OM reference) pointing to that object. This cookie is then usable in the future to get access to the actual object;

    `retrieve:` using the cookie that was obtained earlier by calling the `store` procedure or another procedure call, return an OM object representing the object referred by the cookie;

    `unbind:` remove the object referred by the cookie from the server.

The service provider should be able to decide whether clients are allowed to create remote objects or not.

4. TECHNICAL DESCRIPTIONS

4.1. **Messages to CAS.**

4.1.1. *Procedure call.* The procedure call is an OM object having in general case the following structure:

```
<OMOBJ>
    <OMATTR>
        <!-- beginning of attribution pairs -->
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
```

```
        <OMSTR>call_identifier</OMSTR>
        <OMS cd="scscp1" name="option_runtime" />
        <OMI>runtime_limit_in_milliseconds</OMI>
        <OMS cd="scscp1" name="option_min_memory" />
        <OMI>minimal_memory_required_in_bytes</OMI>
        <OMS cd="scscp1" name="option_max_memory" />
        <OMI>memory_limit_in_bytes</OMI>
        <OMS cd="scscp1" name="option_debuglevel" />
        <OMI>debuglevel_value</OMI>
        <OMS cd="scscp1" name="option_return_object" />
        <!-- another possibility is "option_return_cookie" -->
        <OMSTR></OMSTR>
    </OMATP>
    <!-- Attribution pairs finished, now the procedure call -->
    <OMA>
        <OMS cd="scscp1" name="procedure_call" />
        <OMA>
            <!-- "SCSCP_transient_" is an obligatory prefix
                 in the name of a transient CD -->
            <OMS cd="SCSCP_transient_identifier"
              name="NameOfTheProcedureRegisteredAsWebService" />
            <!-- Argument 1 -->
            <!-- ... -->
            <!-- Argument M -->
        <OMA>
        </OMA>
    </OMA>
  </OMATTR>
</OMOBJ>
```

Remarks:

(1) The definition of the OM symbol `procedure_call` should state that the first OM object is always the name of the procedure registered as WS, and the remaining OM objects are its arguments in the required order.

(2) OM symbols for options will be introduced accordingly to the list of options given in 2.1.1. If the need for new options is discovered, new OM symbols for them should be added to the CD.

(3) Options may be omitted in the procedure call, and in this case their default values must be used. The default values of options may be determined by the service provider, and they are not regulated by the SCSCP specification.

4.1.2. *Interrupt signal.* By design, this message carries no content, the CAS simply needs to be aware that it has received an interrupt.

4.2. **Messages from CAS.**

4.2.1. *Procedure completed.* The procedure completion message is an OM object having in the most general case the following structure:

```
<OMOBJ>
    <OMATTR>
        <!-- Attribution pairs, dependently on the debugging level
             may include procedure name, OM object for the original
             procedure call, etc. -->
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>call_identifier</OMSTR>
            <OMS cd="scscp1" name="info_runtime" />
            <OMI>runtime_in_milliseconds</OMI>
            <OMS cd="scscp1" name="info_memory" />
            <OMI>used_memory_in_bytes</OMI>
        </OMATP>
        <!-- Attribution pairs finished, now the result -->
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <!-- The result itself, may be OM symbol for cookie -->
            <!-- OM_object_corresponding_to_the_result -->
        </OMA>
    </OMATTR>
</OMOBJ>
```

In case the procedure returns a cookie, the returned OM object must have the following structure:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>call_identifier</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed">
            <OMR xref="CAS_variable_identifier" />
        </OMA>
    </OMATTR>
</OMOBJ>
```

4.2.2. *Procedure terminated.* The procedure termination message is an OM object having in the most general case the following structure:

```
<OMOBJ>
    <OMATTR>
        <!-- beginning of attribution pairs -->
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>call_identifier</OMSTR>
            <OMS cd="scscp1" name="info_runtime" />
            <OMI>runtime_in_milliseconds</OMI>
            <OMS cd="scscp1" name="info_memory" />
            <OMI>used_memory_in_bytes</OMI>
```

```
        </OMATP>
        <!-- end of attribution pairs -->
        <!-- now the application part of the OM object -->
        <OMA>
            <OMS cd="scscp1" name="procedure_terminated" />
            <OME>
                <OMS cd="scscp1" name="name_of_standard_error"/>
                <!-- Error description depends on error type -->
                <OMSTR>Error_message</OMSTR>
            </OME>
        </OMA>
    </OMATTR>
</OMOBJ>
```

5. REFERENCE IMPLEMENTATION

In this section we describe a simple implementation suitable for use for local connections on UNIX systems. It may also be usable under Windows provided POSIX signals are available.

To facilitate the implementation, we use XML processing instructions (PI). All PIs defined by SCSCP specification have the form

```
<?scscp [key] [attribute="value" [attribute="value" [...]]] ?>
```

where:

- `key` is an alphanumerical identifier,
- `attribute` is an alphanumerical identifier,
- `value` is an arbitrary string with the same constraints as an XML URI, unless stated otherwise.

Additionally, we allow only those key and attribute identifiers which are described in the present specification. Another strict restriction is that a single SCSCP processing instruction must not exceed 4094 bytes in total, including `<?` and `?>` elements.

5.1. **Connection Initiation.** The software wishing to provide an SCSCP service should listen on port 26133. This port has been assigned to SCSCP by the Internet Assigned Numbers Authority (IANA) in November 2007, see
`http://www.iana.org/assignments/port-numbers`.

Currently, if the port is already in use, it may try to listen to another port, for example by increasing the port number by one until an available port is found. In the future the SCSCP protocol will most likely provide multiplexing possibilities, eliminating the need for this sort of measures.

When a client connects, the CAS should send it a Connection Initiation Message, agree about the protocol version, and then commence an exchange of messages as desribed in section 2.3.

5.1.1. *Connection Initiation Message.* This processing instruction is the first message that the client receives from the server in the beginning of the SCSCP session. Is has the following format:

```
<?scscp service_name="name" service_version="ver"
  service_id="id" scscp_versions="list_of_supported_versions" ?>
```

where

- `"name"` is a string containing the service name, e.g. `"GAPSmallGroups"`, `"KANT"`, `"MapleIntegration"`, `"MuPAD"`, etc.
- `"ver"` is a string containing the version of the service, e.g. `"11"`, `"3.1"`, `"4.1.5beta"`, etc.
- `"id"` is an identifier for the service, **unique** within the SCSCP session (e.g. a hostname-pid combination, a pid, etc.). Note when the hostname is used, it is advised not to trim off any domain information from the hostname to avoid situations when the client connected to multiple hosts may get coinciding service identifiers.
- `scscp_versions` is a space-separated list of identifiers of SCSCP versions supported by the server. Identifier of every single version of SCSCP may contain digits, letters and dots. Versions can be listed in any order. For example, valid value of `scscp_versions` is `"1.0 3.4.1 1.2special"`.

The format of the control sequence is compulsory, and server implementations must not change the order of the attribute/value pairs nor omit some of them. This strict restriction makes it sure that even very simple clients should be able to parse this control sequence.

After receiving clients incoming connection, the SCSCP server must not send to the client anything else before the connection initiation message. The client must wait for this "welcome string" from the server, and must not send to the server any data before obtaining it, since they may be ignored by the server.

5.1.2. *Version negotiation.* To ensure compatibility of various versions of the protocol both upwards and downwards and avoid the scenario where the software supporting the older version of the protocol sends a valid message in that version that is accidentally ignored by the newer version of the protocol or causes another errors, the following version negotiation procedure should be performed.

After obtaining the connection initiation message by the client, the client informs the server about the version of the protocol used by the client, sending the message

```
<?scscp version="client_version" ?>
```

where `"client_version"` is a string denoting the SCSCP versions supported by the client (for example, `"1.0"` or `"3.4.1"` or `"1.2special"`).

As the current rule, we require that an official SCSCP client/server should always support at least the version `"1.0"`.

We expect that the client choose one of the versions listed in the connection initiation message received from the server. However, simple client may ignore that information, because the server will be able to reject client's incompatible versions: after receiving the client's SCSCP versions, the server replies with the quit message, for example `<?scscp quit reason="not supported version" ?>`, if the server does not support the version communicated by the client. If the server supports the client's version, it confirms this, sending to the client the processing instruction

```
<?scscp version="server_version" ?>
```

where `"server_version"` is a string representing the preferred SCSCP version of the server, and starts to wait for messages from the client.

After receiving this server's response, the client may start an ongoing message exchange with the server, if the server confirmed the chosen version. If the client received the quit message, it can not continue communication with the server.

Remember that on the connection initiation phase, the order of messages is very strict:

- after receiving an incoming connection, the SCSCP server must not send to the client anything else before the Connection Initiation Message.
- the client must wait for the Connection Initiation Message from the server, and must not send to the server any data before obtaining it, since they may be ignored by the server.
- after receiving the Connection Initiation Message the client must send its version to the server, otherwise the server will not be able to switch to waiting for procedure calls.
- after receiving the client's version, the server either confirms this to the client, and starts to wait for procedure calls, or rejects it, replying with the quite message.
- only after receiving the server's confirmation of the protocol version, the client is allowed to send procedure calls to the server.

Any other data sent on this phase may be ignored.

The only other allowed control sequence during this phase of the protocol is `<?scscp quit ?>` or `<?scscp quit reason="explanation" ?>`, issued, for example, when one side is not able to accept any version proposed by the other side, or issued under external circumstances, for example, sending messages that are not allowed on this negotiation phase. In either case, the rules of quitting (see below) are applied.

An example of successful version negotiation:

```
Server -> Client:
  <?scscp service_name="MuPADserver" service_version="1.1"
    service_id="host:26133" scscp_versions="1.0 3.4.1 1.2special" ?>
Client -> Server:
  <?scscp version="1.0" ?>
Server -> Client:
  <?scscp version="1.0" ?>
```

An example of failed version negotiation:

```
Server -> Client:
  <?scscp service_name="MuPADserver" service_version="1.1"
    service_id="host:26133" scscp_versions="1.0 3.4.1 1.2special" ?>
Client -> Server:
  <?scscp version="1.5beta" ?>
Server -> Client:
  <?scscp quit reason="non supported version 1.5beta" ?>
```

5.2. **Ongoing message exchange.** All messages except interrupts are delivered as XML processing instructions and OpenMath objects in either the XML or the binary OpenMath encoding, transmitted via the socket connection.

To locate OpenMath objects in the input/output streams, we put them into *transaction blocks*. The transaction block looks as follows:

```
<?scscp start ?>
[a valid OpenMath object]
<?scscp end ?>
```

Another kind of transaction block have the form

```
<?scscp start ?>
[something]
<?scscp cancel ?>
```

and the `<?scscp cancel ?>` instruction indicates that the started transaction block is cancelled. The receiver need not to wait for a matching `<?scscp end ?>` directive, and must not process/evaluate the data in this transaction block.

Another instruction is `<?scscp quit ?>`, which may also be used in the long form `<?scscp quit reason="explanation" ?>`, that indicates that the sender is about to leave the SCSCP session. Then each side may close the socket (and at least the receiver may safely disconnect). This instruction may appear anywhere throughout the session.

Any data after successful version negotiation which are located outside of transaction blocks (apart from PIs) may be safely ignored.

5.3. **Interrupt.** The interrupt signal is delivered by sending SIGUSR2 to the CAS.

5.4. **Other ways of implementation.** We assume that in most cases it will be enough when the SCSCP-compliant CAS will support the scheme outlined above, since this will provide the opportunity to "talk" in clean SCSCP with other CASs supporting this scheme, and with the SCSCP-proxy server, that will accept SOAP/HTTP requests from the outside and then send their SCSCP content to CASs. However, it is conceivable that the CAS itself will be able to receive SOAP/HTTP requests without the mentioned proxy.

The same refers to the client functionality: if there is a server that accepts only SOAP/HTTP requests, then the CAS can send an SCSCP-request to the proxy which then will act as a proper Web services client, or might be able to wrap SCSCP procedure call into SOAP/HTTP envelope itself.

Details of such implementations (WSDL descriptions of Web services provided by the SCSCP-proxy server etc.) will be specified soon on the next stage of the project.

6. Appendix A.

The list of OM symbols defined in the scscp1 CD

The scscp1 CD [1] defines OM symbols for main types of messages and attributes that may appear in them:

(1) Main messages:
- procedure_call
- procedure_completed
- procedure_terminated

(2) Call and response identifiers:
- call_ID

(3) Options in procedure calls:
- option_max_memory
- option_min_memory
- option_runtime
- option_debuglevel
- option_return_cookie
- option_return_object
- option_return_nothing

(4) Information attributes:
- info_memory
- info_runtime

(5) Standard errors:
- error_memory
- error_runtime
- error_system_specific

See the scscp1 CD [1] for the appropriate descriptions.

The list of OM symbols defined in the scscp2 CD

The scscp2 CD [2] defines OM symbols for special procedures, and also some symbols that may appear in their arguments and results:

(1) Procedures for work with remote objects:
- store
- retrieve
- unbind

(2) Special procedures to obtain meta-information about SCSCP service:
- get_allowed_heads
- get_transient_cd
- get_signature
- get_service_description

(3) Special symbols:
- signature
- service_description
- symbol_set
- symbol_set_all
- no_such_transient_cd

See the scscp2 CD [2] for the appropriate descriptions.

7. Appendix B.

Examples of OM messages

B.1 An example of the `procedure_call` message

`GroupIdentificationService` accepts permutation group G given by its generators and returns the `procedure_completed` message with the number of this group in the GAP Small Groups Library, or the `procedure_terminated` message groups of order $|G|$ are not contained in that library or identification for groups of such order is not available in GAP.

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
            <OMS cd="scscp1" name="option_runtime" />
            <OMI>300000</OMI>
            <OMS cd="scscp1" name="option_min_memory" />
            <OMI>40964</OMI>
            <OMS cd="scscp1" name="option_max_memory" />
            <OMI>134217728</OMI>
            <OMS cd="scscp1" name="option_debuglevel" />
            <OMI>2</OMI>
            <OMS cd="scscp1" name="option_return_object" />
            <OMSTR></OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_call" />
            <OMA>
                <OMS cd="SCSCP_transient_1"
                  name="GroupIdentificationService" />
                <OMA>
                    <OMS cd="group1" name="group"/>
                    <OMA>
                        <OMS cd="permut1" name="permutation"/>
                        <OMI> 2</OMI> <OMI> 3</OMI>
                        <OMI> 1</OMI>
                    </OMA>
                    <OMA>
                        <OMS cd="permut1" name="permutation"/>
                        <OMI> 1</OMI> <OMI> 2</OMI>
                        <OMI> 4</OMI> <OMI> 3</OMI>
                    </OMA>
                </OMA>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

In the next example we retrieve the group [24,12] from GAP Small Groups Library, creating it at the GAP side and requesting a cookie for it:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
            <OMS cd="scscp1" name="option_return_cookie" />
            <OMSTR></OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_call" />
            <OMA>
                <OMS cd="SCSCP_transient_1" name="GroupByIdNumber" />
                <OMI>24</OMI><!-- Arg1 --><OMI>12</OMI><!-- Arg2 -->
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

In the next example we are sending an OM object containing MathML object:

```
<OMOBJ>
  <OMATTR>
    <OMATP>
      <OMS cd="scscp1" name="call_ID"/>
      <OMSTR>a1d0c6e83f027327d8461063f4ac58a6</OMSTR>
      <OMS cd="scscp1" name="option_return_cookie"/>
      <OMSTR></OMSTR>
    </OMATP>
    <OMA>
      <OMS cd="scscp1" name="procedure_call"/>
      <OMA>
        <OMS cd="SCSCP_transient_M25" name="Evaluate" />
        <OMA>
          <OMS cd="altenc" name="MathML_encoding"/>
          <OMFOREIGN encoding="MathML-Presentation">
            <math xmlns="http://www.w3.org/1998/Math/MathML">
              <mrow>
                <mi>sin</mi>
                <mo>&ApplyFunction;</mo>
                <mfenced><mi>x</mi></mfenced>
              </mrow>
            </math>
          </OMFOREIGN>
        </OMA>
      </OMA>
    </OMA>
  </OMATTR>
</OMOBJ>
```

B.2 An example of the `procedure_completed` message

The procedure `GroupIdentificationService` from the previous example returns its successful output in the following form:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
            <OMS cd="scscp1" name="info_runtime" />
            <!-- The runtime in milliseconds as OM integer -->
            <OMI>1234</OMI>
            <OMS cd="scscp1" name="info_memory" />
            <!-- Memory occupied by CAS in bytes as OM integer -->
            <OMI>134217728</OMI>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <OMA>
                <OMS cd="linalg2" name="vector"/>
                <OMI> 24</OMI>
                <OMI> 12</OMI>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

In the case when a cookie is requested, the `procedure_completed` message may look as follows (we assume the minimal debugging level with no information about the runtime and memory used):

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed">
            <OMR xref="scscp://somehost.somedomain:26133/q9t4eX" />
        </OMA>
    </OMATTR>
</OMOBJ>
```

B.3 An example of the `procedure_terminated` message

This is an example how the procedure `GroupIdentificationService` may return an error message if the error arises at the CAS level (we assume the minimal debugging level with no information about the runtime and memory used):

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_terminated" />
            <OME>
                <OMS cd="scscp1" name="error_CAS"/>
                <OMSTR>Error, the group identification for groups of size\n
                        3628800 is not available called from\n
                        <function>( <arguments> ) called from read-eval-loop\n
                        Entering break read-eval-print loop ...\n
                        you can 'quit;' to quit to outer loop, or\n
                        you can 'return;' to continue\n
                        brk>\n
                </OMSTR>
            </OME>
        </OMA>
    </OMATTR>
</OMOBJ>
```

One of standard errors on the SCSCP level may look as follows:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_terminated" />
            <OME>
                <OMS cd="scscp1" name="error_memory"/>
                <OMSTR>Exceeded the permitted memory</OMSTR>
            </OME>
        </OMA>
    </OMATTR>
</OMOBJ>
```

8. Appendix C.

Examples of special procedures

C.1 Let us consider the `GroupIdentificationService` from the example in the appendix B. To find the list of procedures supported by the SCSCP server, the client sends to the server the following message:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_call" />
            <OMA>
                <OMS cd="scscp2" name="get_allowed_heads" />
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

The server replies then with the next message, demonstrating all possible arguments of the `symbol_set` OpenMath symbol: symbols from transient CD, created by the service provider, a symbol from a standard CD, a CD and a CD group.

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9053</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <OMA>
                <OMS cd="scscp2" name="symbol_set"/>
                <OMS cd="SCSCP_transient_1"
                   name="GroupIdentificationService" />
                <OMS cd="group1" name="group" />
                <OMA>
                    <OMS cd="meta" name="CDName"/>
                    <OMSTR>permut1</OMSTR>
                </OMA>
                <OMA>
                    <OMS cd="metagrp" name="CDGroupName"/>
                    <OMSTR>scscp</OMSTR>
                </OMA>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

Now the client is interested in getting the transient CD `SCSCP_transient_1`, and sends to the server the procedure call displayed below.

Note that in this example we assume that the `SCSCP_transient_1` CD contains just one symbol `GroupIdentificationService`, so the server may equally return just `CDName` with `SCSCP_transient_1` instead of one symbol. In such a case the client may then use `get_transient_cd` procedure to get the corresponding CD in order to find out which namely procedures are defined in it.

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9054</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_call" />
            <OMA>
                <OMS cd="scscp2" name="get_transient_cd" />
                <OMA>
                    <OMS cd="meta" name="CDName"/>
                    <OMSTR>SCSCP_transient_1</OMSTR>
                </OMA>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

In response to this procedure call, the server sends to the client the transient CD in the following message:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9054</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <OMA>
                <OMS cd="meta" name="CD"/>
                <OMA>
                    <OMS cd="meta" name="CDName"/>
                    <OMSTR>SCSCP_transient_1</OMSTR>
                </OMA>
                <OMA>
                    <OMS cd="meta" name="CDDate"/>
                    <OMSTR>2007-08-24</OMSTR>
                </OMA>
                <OMA>
                    <OMS cd="meta" name="Description"/>
                    <OMSTR>CD created by the service provider</OMSTR>
```

```
                </OMA>
                <OMA>
                    <OMS cd="meta" name="CDDefinition"/>
                    <OMA>
                        <OMS cd="meta" name="Name"/>
                        <OMSTR>GroupIdentificationService</OMSTR>
                    </OMA>
                    <OMA>
                        <OMS cd="meta" name="Description"/>
                        <OMSTR>IdGroup(permgroup by gens)</OMSTR>
                    </OMA>
                </OMA>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

We assume that when the procedure is installed as an SCSCP procedure, the CAS assign the name to the transient CD, saves the time of its creation, and put some textual information, specified by the service provider, to its description. Also at this step the service provider must specify the signature of this procedure, which then can be retrieved by the client by sending the following message to the server:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9055</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_call" />
            <OMA>
                <OMS cd="scscp2" name="get_signature" />
                <OMS cd="SCSCP_transient_1"
                    name="GroupIdentificationService" />
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

The server then replies with the following message:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9055</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <OMA>
                <OMS cd="scscp2" name="signature"/>
```

```
                <OMS cd="SCSCP_transient_1"
                   name="GroupIdentificationService" />
                <OMI>1</OMI>
                <OMI>1</OMI>
                <OMA>
                    <OMS cd="list1" name="list"/>
                    <OMA>
                       <OMS cd="scscp2" name="symbol_set"/>
                       <OMS cd="group1" name="group"/>
                       <OMA>
                          <OMS cd="meta" name="CDName"/>
                          <OMSTR>permut1</OMSTR>
                       </OMA>
                    </OMA>
                </OMA>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

The list containing one `symbol_set` symbol in the signature means that its first element represents the set of accepted symbols for the first (and unique) argument. In case when the maximum number of arguments is not specified, we will use just one `symbol_set` symbol not enclosed in the list. Also note that we allow procedure calls when the actual number of arguments is smaller than the maximal, and in this case extra entries of this list will be ignored.

C.2. An example of the signature of some generic CAS service, that does not restrict the number of arguments, but exposes to the client the list of supported CDs and CD groups:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9088</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <OMA>
                <OMS cd="scscp2" name="signature"/>
                <OMS cd="SCSCP_transient_1" name="CAS_Service" />
                <OMI>0</OMI>
                <OMS cd="nums1" name="infinity"/>
                <OMA>
                    <OMS cd="scscp2" name="symbol_set"/>
                    <OMA>
                      <OMS cd="meta" name="CDGroupName"/>
                      <OMSTR>scscp</OMSTR>
                    </OMA>
                    <OMA>
```

```
                              <OMS cd="meta" name="CDName"/>
                              <OMSTR>SCSCP_transient_0</OMSTR>
                          </OMA>
                          <OMA>
                              <OMS cd="meta" name="CDName"/>
                              <OMSTR>SCSCP_transient_1</OMSTR>
                          </OMA>
                          <OMA>
                              <OMS cd="meta" name="CDName"/>
                              <OMSTR>arith1</OMSTR>
                          </OMA>
                          <OMA>
                              <OMS cd="meta" name="CDName"/>
                              <OMSTR>transc1</OMSTR>
                          </OMA>
                      </OMA>
                  </OMA>
              </OMA>
          </OMATTR>
  </OMOBJ>
```

C.3. Another example demonstrates default "universal" signature that may be returned in case when nothing was specified during the installation of the SCSCP procedure on the server:

```
<OMOBJ>
    <OMATTR>
        <OMATP>
            <OMS cd="scscp1" name="call_ID" />
            <OMSTR>alexk_9088</OMSTR>
        </OMATP>
        <OMA>
            <OMS cd="scscp1" name="procedure_completed" />
            <OMA>
                <OMS cd="scscp2" name="signature"/>
                <OMS cd="SCSCP_transient_1" name="Something" />
                <OMI>0</OMI>
                <OMS cd="nums1" name="infinity"/>
                <OMS cd="scscp2" name="symbol_set_all"/>
            </OMA>
        </OMA>
    </OMATTR>
</OMOBJ>
```

References

[1] D. Roozemond. *OpenMath* *Content* *Dictionary* `scscp1`. (`http://www.win.tue.nl/SCIEnce/cds/scscp1.html`).

[2] D. Roozemond. *OpenMath* *Content* *Dictionary* `scscp2`. (`http://www.win.tue.nl/SCIEnce/cds/scscp2.html`).

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