Network Working Group T. Mizrahi
Internet Draft Y. Moses
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Time Capability in NETCONF
draft-mm-netconf-time-capability-03.txt

Abstract

This document defines a capability-based extension to the Network Configuration Protocol (NETCONF) that allows time-triggered configuration and management operations. This extension allows NETCONF clients to invoke configuration updates according to scheduled times, and allows NETCONF servers to attach timestamps to the data they send to NETCONF clients.

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1. Introduction

The Network Configuration Protocol (NETCONF) defined in [RFC6241] provides mechanisms to install, manipulate, and delete the

configuration of network devices. NETCONF allows clients to configure and monitor NETCONF servers using remote procedure calls (RPC).

NETCONF, as defined in [RFC6241], is asynchronous; when a client invokes an RPC, it has no control over the time at which the RPC is executed, nor does it have any feedback from the server about the execution time.

Time-based configuration ([HotSDN], [TimeTR]) can be a useful tool that enables an entire class of coordinated and scheduled configuration procedures. Time-triggered configuration allows coordinated network updates in multiple devices; a client can invoke a coordinated configuration change by sending RPCs to multiple servers with the same scheduled execution time. A client can also invoke a time-based sequence of updates by sending n RPCs with n different update times, T1, T2, ..., Tn, determining the order in which the RPCs are executed.

This memo defines the time capability in NETCONF. This extension allows clients to determine the scheduled execution time of RPCs they send. It also allows a server that receives an RPC to report its actual execution time to the client.

2. Conventions used in this document

2.1. Keywords

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2199].

2.2. Abbreviations

NETCONF Network Configuration Protocol

RPC Remote Procedure Call

2.3. Terminology

- Capability [RFC6142]: A functionality that supplements the base NETCONF specification.

- Client [RFC6142]: Invokes protocol operations on a server. In addition, a client can subscribe to receive notifications from a server.

- Execution time: The execution time of an RPC is defined as the time at which a server completes the execution of an RPC.

- Scheduled time: The scheduled time of an RPC is the time at which the RPC should be invoked. The scheduled time is determined by the client, and enforced by the server.

- Server [RFC6142]: Executes protocol operations invoked by a client. In addition, a server can send notifications to a client.

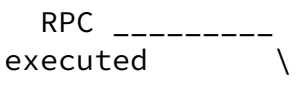
3. Using Time in NETCONF

3.1. The Time Capability in a Nutshell

The :time capability provides two main functions:

- Scheduling:
  When a client sends an RPC to a server, the RPC message MAY include a scheduled time, Ts (see Figure 1). The server then executes the RPC at the scheduled time Ts, and once completed the server can respond with an RPC reply message.

- Reporting:
  When a client sends an RPC to a server, the RPC message MAY include a get-time element (see Figure 2), requesting the server to return the execution time of the RPC. In this case, after the server performs the RPC it responds with an RPC reply that includes the execution time, Te.



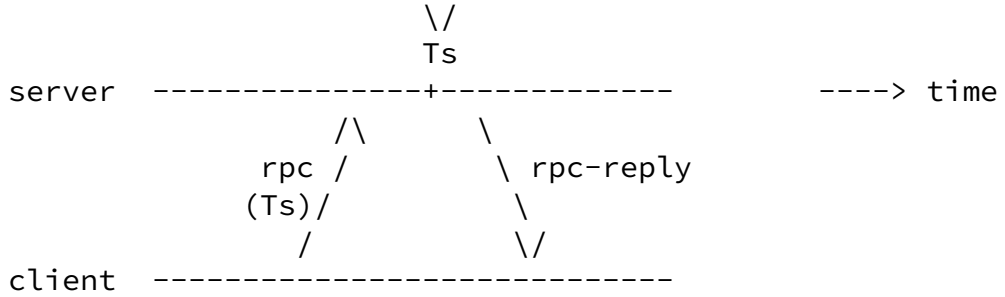


Figure 1 Scheduled RPC

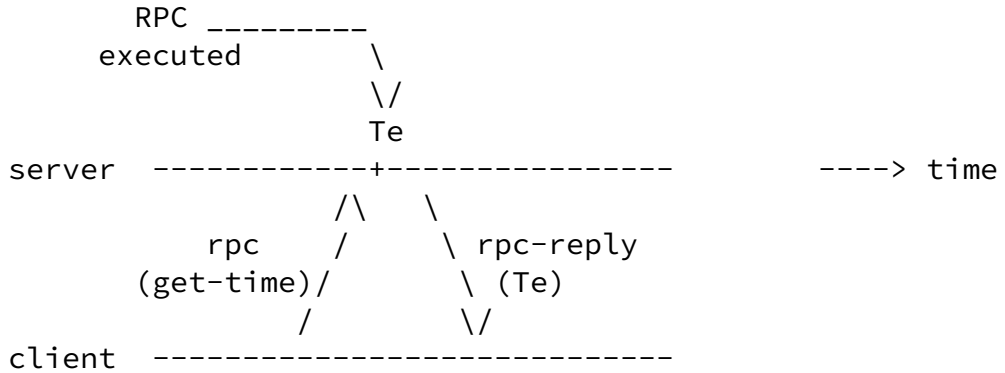
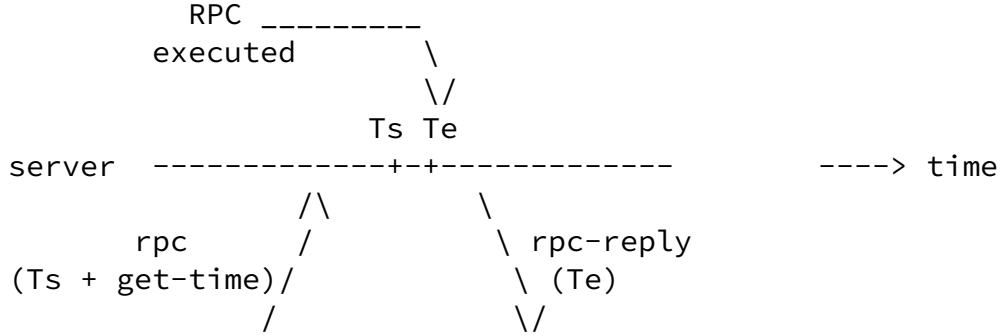


Figure 2 Reporting the Execution Time of an RPC

The two scenarios discussed above imply that a third scenario can also be supported (Figure 3), where the client invokes an RPC that includes a scheduled time, Ts, as well as the get-time element. This allows the client to receive feedback about the actual execution time, Te. Ideally, Ts=Te. However, the server may execute the RPC at a slightly different time than Ts, for example if the server is tied up with other tasks at Ts.



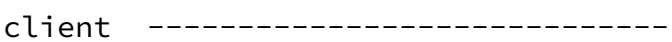


Figure 3 Scheduling and Reporting

3.2. Notifications and Cancellation Messages

Notifications

As illustrated in Figure 1, after a scheduled RPC is executed the server sends an rpc-reply. The rpc-reply may arrive a long period of time after the RPC was sent by the client, leaving the client without a clear indication of whether the RPC was received.

This document defines a new notification, the netconf-scheduled-message notification, which provides an immediate acknowledgement of the scheduled RPC.

The netconf-scheduled-message is sent to the client if it is subscribed to the NETCONF notifications [RFC6470]; as illustrated in Figure 4, when the server receives a scheduled RPC it sends a notification that includes the message-id of the scheduled RPC.

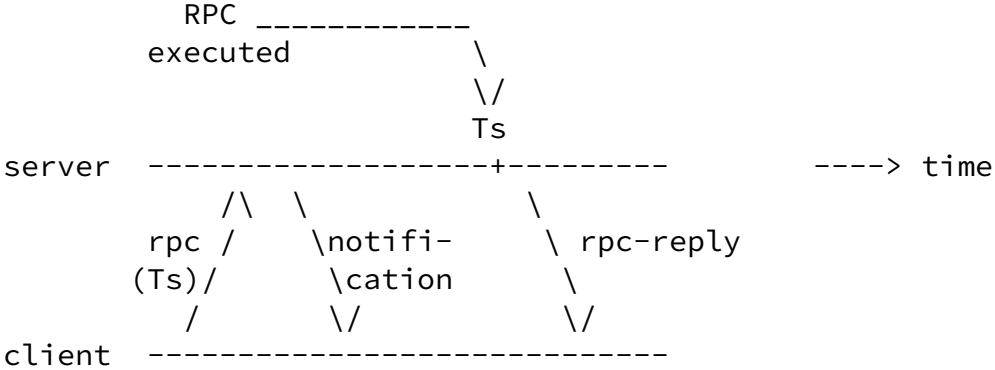


Figure 4 Scheduled RPC with Notification

Cancellation Messages

A client can cancel a scheduled RPC by sending a <cancel-schedule> RPC.

The <cancel-schedule> RPC, defined in this document, can be used to

perform a coordinated all-or-none procedure, where either all the servers perform the operation on schedule, or the operation is aborted.

Example. The client sends scheduled RPC messages to server 1 and server 2, both scheduled to Ts. Server 1 sends a notification that indicates it has successfully schedled the RPC, while server 2 replies with an unknown-element error [RFC6241] that indicates that it does not support the time capability. The client sends a <cancel-schedule> RPC to server 1, and receives an rpc-reply. The message exchange between the client and server 1 in this example is illustrated in Figure 5.

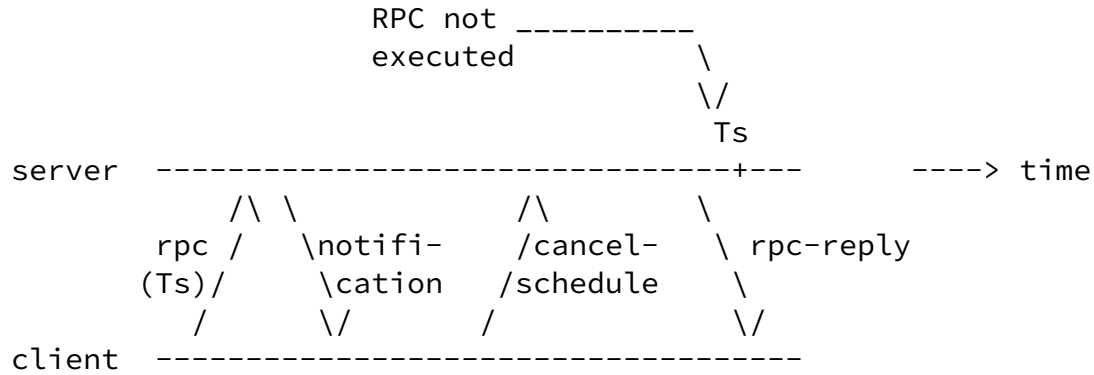


Figure 5 Cancellation Message

3.3. Synchronization Aspects

The time capability defined in this document requires clients and servers to maintain clocks. It is assumed that clocks are synchronized by a method that is outside the scope of this document, e.g., [NTP] or [IEEE1588].

This document does not define any requirements pertaining to the degree of accuracy of performing scheduled RPCs. Note that two factors affect how accurately the server can perform a scheduled RPC; one factor is the accuracy of the clock synchronization method used to synchronize the clients and servers, and the second factor is the

server's ability to execute real-time configuration changes, which greatly depends on how it is implemented. Typical networking devices are implemented by a combination of hardware and software. While the execution time of a hardware module can typically be predicted with a high level of accuracy, the execution time of a software module may be variable and hard to predict. A configuration update would typically require the server's software to be involved, thus affecting how accurately the RPC can be scheduled.

Another important aspect of synchronization, is monitoring; a client should be able to check whether a server is synchronized to a reference time source. Typical synchronization protocols, such as the Network Time Protocol ([NTP], [RFC5907]) provide the means to verify that a clock is synchronized to a time reference by querying its Management Information Base (MIB). The get-time feature defined in this document (see Figure 2) allows a client to obtain a rough estimate of the time offset between the client's clock and the server's clock.

Since servers do not perform configuration changes instantaneously, the processing time of an RPC should not be overlooked. The scheduled time always refers to the start time of the RPC, and the execution time always refers to its completion time.

3.4. Scheduled Time Format

The scheduled time and execution time fields in RPC messages use a common time format field.

The time format used in this document is the date-and-time format, that is defined in Section 5.6 of [RFC3339] and in Section 3 of [RFC6021].

```
leaf scheduled-time {
  description
  "The time at which the RPC is scheduled to be performed.";
  type yang:date-and-time;
}
```

```
      leaf execution-time {
        description
        "The time at which the RPC was executed.";
        type yang:date-and-time;
      }
```

3.5. Scheduling Tolerance

When a client sends an RPC that is scheduled to Ts, the server MUST verify that the value Ts is not too far in the past or in the future. As illustrated in Figure 6, the server verifies that Ts is within the scheduling tolerance range.

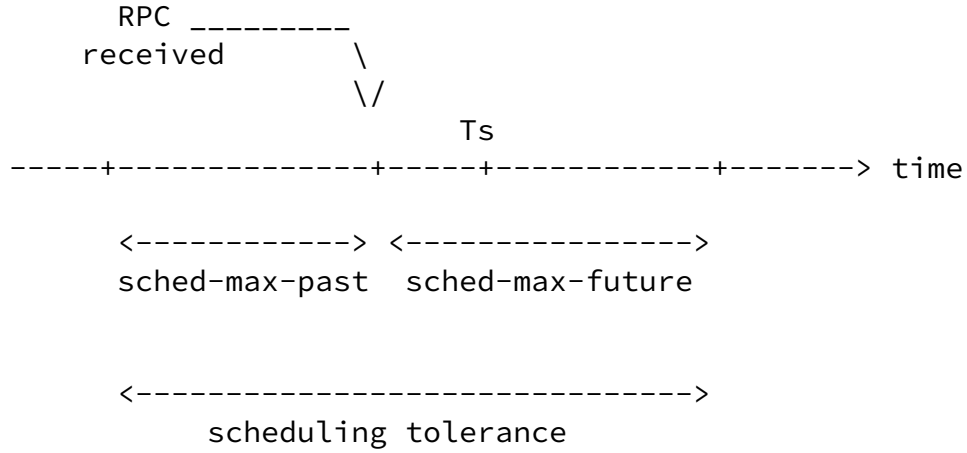


Figure 6 Scheduling Tolerance

The scheduling tolerance is determined by two parameters, sched-max-future and sched-max-past. These two parameters use the time-interval format (Section 3.7.), and their default value is 15 seconds.

If the scheduled time, Ts is within the scheduling tolerance range, the scheduled RPC is performed; if Ts occurs in the past and within the scheduling tolerance, the server performs the RPC as soon as possible, whereas if Ts is a future time, the server performs the RPC at Ts.

If Ts is not within the scheduling tolerance range, the server responds with an error message [RPC6241] with a bad-element error-tag. An example is provided in Section 5.3.

3.6. Near Future Scheduling vs. Far Future Scheduling

The scheduling bound defined by sched-max-future guarantees that every scheduled RPCs is restricted to a near future scheduling time.

The scheduling mechanism defined in this document is intended for near future scheduling, on the order of seconds. Far future scheduling is outside the scope of this document.

The challenge in far future scheduling is that during the long period between the time at which the RPC is sent and the time at which it is scheduled to be executed various external events may occur, e.g., the client may fail or reboot, or the client access permissions may be changed. In these cases if the server performs the scheduled operation it may perform an action that is inconsistent with the

current network policy, or inconsistent with the currently active clients.

Near future scheduling guarantees that external events such as the examples above have a low probability of occurring during the sched-max-future period, and even when they do, the period of inconsistency is limited to sched-max-future, which is a short period of time.

3.7. Time Interval Format

The time-interval format is used for representing the length of a time interval, and is based on the date-and-time format. It is used for representing the scheduling tolerance parameters, as described in the previous section.

While the date-and-time type uniquely represents a specific point in

time, the time-interval type defined below can be used to represent the length of a time interval without specifying a specific date.

The time-interval type is defined as follows:

```
   typedef time-interval {
     type string {
       pattern '\d{2}:\d{2}:\d{2}(\.\d+)?';
     }
   }
```

4. Time Capability

The structure of this section is as defined in Appendix D of [RFC6241].

4.1. Overview

A server that supports the time capability can perform time-triggered operations as defined in this document.

A server implementing the :time capability:

- MUST support the ability to receive <rpc> messages that include a time element, and perform a time-triggered operation accordingly.

- MUST support the ability to include a time element in the <rpc-reply> messages that it transmits.

4.2. Dependencies

With-defaults Capability

The time capability YANG module (Appendix A.) uses default values, and thus it is assumed that the with-defaults capability [RFC6243] is supported.

4.3. Capability Identifier

The :time capability is identified by the following capability string (to be assigned by IANA - see Section 7.):

urn:ietf:params:netconf:capability:time:1.0

4.4. New Operations

<cancel-schedule>

The cancel-schedule RPC is used for cancelling an RPC that was previously scheduled.

A cancel-schedule RPC MUST include the <cancelled-message-id> element, which specifies the message ID of the scheduled RPC that needs to be cancelled.

A cancel-schedule RPC MAY include the <get-time> element. In this case the rpc-reply includes the <execution-time> element, specifying the time at which the scheduled RPC was cancelled.

4.5. Modifications to Existing Operations

Three new elements are added to all existing operations:

- <scheduled-time>
  This element is added to the input of each operation, indicating the time at which the server is scheduled to invoke the operation. Every <rpc> message MAY include the <scheduled-time> element. A server that supports the :time capability and receives an <rpc> message with a <scheduled-time> element MUST perform the operation as close as possible to the scheduled time.

  The scheduled-time element uses the date-and-time format (Section 3.4.).

- <get-time>
  This element is added to the input of each operation. An <rpc> message MAY include a <get-time> element, indicating that the server MUST include an <execution-time> in its corresponding <rpc-reply>.

- <execution-time>

This element is added to the output of each operation, indicating the time at which the server completed the operation. An <rpc-reply> MAY include the <execution-time> element. A server that supports the :time capability and receives an operation with the <get-time> element MUST include the execution time in its response.

The execution-time element uses the date-and-time format (Section 3.4.).

4.6. Interactions with Other Capabilities

Confirmed Commit Capability

The confirmed commit capability is defined in Section 8.4 of [RFC6241]. According to [RFC6241], a confirmed <commit> operation MUST be reverted if a confirming commit is not issued within the timeout period (which by default is 600 seconds).

When the time capability is supported, and a confirmed <commit> operation is used with the <scheduled-time> element, the confirmation timeout MUST be counted from the scheduled time, i.e., the client begins the timeout measurement starting at the scheduled time.

5. Examples

5.1. <scheduled-time> Example

The following example extends the example presented in Section 7.2 of [RFC6241] by adding the time capability. In this example, the <scheduled-time> element is used to specify the scheduled execution time of the configuration update (as shown in Figure 1).

```
<rpc message-id="101"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
```



```
    <scheduled-time
       xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-time">
        2015-10-21T04:29:00.235Z
```

```
      </scheduled-time>
      <config>
        <top xmlns="http://example.com/schema/1.2/config">
          <interface>
            <name>Ethernet0/0</name>
            <mtu>1500</mtu>
          </interface>
        </top>
      </config>
    </edit-config>
  </rpc>

  <rpc-reply message-id="101"
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <ok/>
  </rpc-reply>
```

5.2. <get-time> Example

The following example is similar to the one presented in Section 5.1. , except that in this example the client includes a <get-time> element in its RPC, and the server consequently responds with an <execution-time> element (as shown in Figure 2).

```
  <rpc message-id="101"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <edit-config>
      <target>
        <running/>
      </target>
      <get-time
       xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-time">
      </get-time>
      <config>
        <top xmlns="http://example.com/schema/1.2/config">
          <interface>
            <name>Ethernet0/0</name>
            <mtu>1500</mtu>
```



```
          </interface>
        </top>
      </config>
```

```
    </edit-config>
  </rpc>

  <rpc-reply message-id="101"
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <ok/>
    <execution-time>
        2015-10-21T04:29:00.235Z
    </execution-time>
  </rpc-reply>
```

5.3. Error Example

The following example presents a scenario in which the scheduled-time is not within the scheduling tolerance, i.e., it is too far in the past, and therefore an rpc-error is returned.

```
  <rpc message-id="101"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <edit-config>
      <target>
        <running/>
      </target>
      <scheduled-time
         xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-time">
          2010-10-21T04:29:00.235Z
      </scheduled-time>
      <config>
        <top xmlns="http://example.com/schema/1.2/config">
          <interface>
            <name>Ethernet0/0</name>
            <mtu>1500</mtu>
          </interface>
        </top>
      </config>
    </edit-config>
  </rpc>

  <rpc-reply message-id="101"
```



```
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <rpc-error>
      <error-type>application</error-type>
```

```
      <error-tag>bad-element</error-tag>
      <error-severity>error</error-severity>
      <error-info>
        <bad-element>scheduled-time</bad-element>
      </error-info>
    </rpc-error>
  </rpc-reply>
```

6. Security Considerations

The security considerations of the NETCONF protocol in general are discussed in [RFC6241].

The usage of the time capability defined in this document can assist an attacker in gathering information about the system, such as the exact time of future configuration changes. Moreover, the time elements can potentially allow an attacker to learn information about the system's performance. Furthermore, an attacker that sends malicious RPC messages can use the time capability to amplify her attack; for example, by sending multiple RPC messages with the same scheduled time. It is important to note that the security measures described in [RFC6241] can prevent these vulnerabilities.

The time capability relies on an underlying time synchronization protocol. Thus, an attack against the time protocol can potentially compromise NETCONF when using the time capability. A detailed discussion about the threats against time protocols and how to mitigate them is presented in [TimeSec].

7. IANA Considerations

This document proposes to register the following capability identifier URN in the 'Network Configuration Protocol (NETCONF) Capability URNs' registry:

```
     urn:ietf:params:netconf:capability:time:1.0
```

This document proposes to register the following XML namespace URN in the 'IETF XML registry', following the format defined in [RFC3688]:

```
      URI: urn:ietf:params:xml:ns:yang:ietf-netconf-time
```

This document proposes to register a module name in the 'YANG Module Names' registry, defined in [RFC6020].

name: ietf-netconf-time

prefix: nct

namespace: urn:ietf:params:xml:ns:yang:ietf-netconf-time

RFC: TBD

8. Acknowledgments

The authors gratefully acknowledge Joe Marcus Clarke, Andy Bierman, Balazs Lengyel, Jonathan Hansford, Alon Schneider and Eylon Egozi for their insightful comments.

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This document was prepared using 2-Word-v2.0.template.dot.

9. References

9.1. Normative References

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http://tx.technion.ac.il/~dew/OFTimeTR.pdf

Appendix A. YANG Module for the Time Capability

This section is normative.

<CODE BEGINS> file "ietf-netconf-time@2014-06-26.yang"

```
module ietf-netconf-time {

   namespace "urn:ietf:params:xml:ns:yang:ietf-netconf-time";

   prefix nct;

   import ietf-netconf { prefix nc; }
```

```
      import ietf-yang-types { prefix yang; }

      import ietf-netconf-monitoring { prefix ncm; }

      contact
        "Editor: Tal Mizrahi
            <dew@tx.technion.ac.il>
         Editor: Yoram Moses
            <moses@ee.technion.ac.il>";

      description
        "This module defines a capability-based extension to the
         Network Configuration Protocol (NETCONF) that allows
         time-triggered configuration and management operations.
         This extension allows NETCONF clients to invoke configuration
         updates according to scheduled times, and allows NETCONF
         servers to attach timestamps to the data they send to NETCONF
         clients.";

      revision 2014-06-26 {
         description
           "Initial version.";
         reference
           "draft-mm-netconf-time-capability:
            Time Capability in NETCONF";
      }



      typedef time-interval {
         type string {
            pattern '\d{2}:\d{2}:\d{2}(\.\d+)?';
         }
      }


      grouping scheduling-tolerance-parameters {
         description
           "Contains the parameters of the scheduling tolerance.";

         leaf sched-max-future {
            description
```

```
              "When the scheduled time is in the future, i.e., greater
               than the present time, this leaf defines the maximal
               difference between the scheduled time
```



```
               and the present time that the server is willing to
               accept. If the difference exceeds this number, the
               server responds with an error.";
            type time-interval;
            default 00:00:15.0;
         }

         leaf sched-max-past {
            description
              "When the scheduled time is in the past, i.e., less
               than the present time, this leaf defines the maximal
               difference between the present time
               and the scheduled time that the server is willing to
               accept. If the difference exceeds this number, the
               server responds with an error.";
            type time-interval;
            default 00:00:15.0;
         }
      }


      // extending the get-config operation
      augment /nc:get-config/nc:input {
         description
           "Adds the time element to <get-config>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }
```

```
augment /nc:get-config/nc:output {
```



```
   description
     "Adds the time element to <get-config>.";

   leaf execution-time {
      description
        "The time at which the RPC was executed.";
      type yang:date-and-time;
   }
}


augment /nc:get/nc:input {
   description
     "Adds the time element to <get>.";

   leaf scheduled-time {
      description
        "The time at which the RPC is scheduled to be performed.";
      type yang:date-and-time;
   }

   leaf get-time {
      description
        "Indicates that the rpc-reply should include the
         execution-time.";
      type empty;
   }
}

augment /nc:get/nc:output {
   description
     "Adds the time element to <get>.";

   leaf execution-time {
      description
        "The time at which the RPC was executed.";
      type yang:date-and-time;
   }
}
```

```
      augment /nc:copy-config/nc:input {
```



```
         description
           "Adds the time element to <copy-config>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }

      augment /nc:copy-config/nc:output {
         description
           "Adds the time element to <copy-config>.";

         leaf execution-time {
            description
              "The time at which the RPC was executed.";
            type yang:date-and-time;
         }
      }

      augment /nc:edit-config/nc:input {
         description
           "Adds the time element to <edit-config>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
```

```
            execution-time.";
          type empty;
       }
    }

    augment /nc:edit-config/nc:output {
       description
         "Adds the time element to <edit-config>.";

       leaf execution-time {
          description
            "The time at which the RPC was executed.";
          type yang:date-and-time;
       }
    }

    augment /nc:delete-config/nc:input {
       description
         "Adds the time element to <delete-config>.";

       leaf scheduled-time {
          description
            "The time at which the RPC is scheduled to be performed.";
          type yang:date-and-time;
       }

       leaf get-time {
          description
            "Indicates that the rpc-reply should include the
             execution-time.";
          type empty;
       }
    }

    augment /nc:delete-config/nc:output {
       description
         "Adds the time element to <delete-config>.";

       leaf execution-time {
          description
            "The time at which the RPC was executed.";
```

```
            type yang:date-and-time;
         }
      }

      augment /nc:lock/nc:input {
         description
           "Adds the time element to <lock>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }

      augment /nc:lock/nc:output {
         description
           "Adds the time element to <lock>.";

         leaf execution-time {
            description
              "The time at which the RPC was executed.";
            type yang:date-and-time;
         }
      }

      augment /nc:unlock/nc:input {
         description
           "Adds the time element to <unlock>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
```

```
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }

      augment /nc:unlock/nc:output {
         description
           "Adds the time element to <unlock>.";

         leaf execution-time {
            description
              "The time at which the RPC was executed.";
            type yang:date-and-time;
         }
      }

      augment /nc:close-session/nc:input {
         description
           "Adds the time element to <close-session>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }

      augment /nc:close-session/nc:output {
         description
```

```
            "Adds the time element to <close-session>.";

         leaf execution-time {
            description
              "The time at which the RPC was executed.";
            type yang:date-and-time;
         }
      }

      augment /nc:kill-session/nc:input {
         description
           "Adds the time element to <kill-session>.";

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }

      augment /nc:kill-session/nc:output {
         description
           "Adds the time element to <kill-session>.";

         leaf execution-time {
            description
              "The time at which the RPC was executed.";
            type yang:date-and-time;
         }
      }

      augment /nc:commit/nc:input {
         description
           "Adds the time element to <commit>.";
```

```
         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }

         leaf get-time {
            description
              "Indicates that the rpc-reply should include the
               execution-time.";
            type empty;
         }
      }

      augment /nc:commit/nc:output {
         description
           "Adds the time element to <commit>.";

         leaf execution-time {
            description
              "The time at which the RPC was executed.";
            type yang:date-and-time;
         }
      }

      augment /ncm:netconf-state {
         container scheduling-tolerance {
            description
              "The scheduling tolerance when the time capability
               is enabled.";
            uses scheduling-tolerance-parameters;
         }
      }

      rpc cancel-schedule {
         description
           "Cancels a scheduled message.";
         reference
           "draft-mm-netconf-time-capability:
            Time Capability in NETCONF";
```

```
         input {
            leaf cancelled-message-id {
               description
                 "The ID of the message to be cancelled.";
                  type string;
            }
            leaf get-time {
               description
                 "Indicates that the rpc-reply should include
                  the execution-time.";
               type empty;
            }
         }
         output {
            leaf execution-time {
               description
                 "The time at which the RPC was executed.";
               type yang:date-and-time;
            }
         }
      }

      notification netconf-scheduled-message {
         description
           "Indicates that a scheduled message was received.";
         reference
           "draft-mm-netconf-time-capability:
            Time Capability in NETCONF";

         leaf scheduled-message-id {
            description
              "The ID of the scheduled message.";
            type string;
         }

         leaf scheduled-time {
            description
              "The time at which the RPC is scheduled to be performed.";
            type yang:date-and-time;
         }
```

```
      }

   }
   <CODE ENDS>
```

Authors' Addresses

Tal Mizrahi
7/43 Gotl Levin st.
Haifa, 3292207, Israel

Email: dew@tx.technion.ac.il

Yoram Moses
Department of Electrical Engineering
Technion - Israel Institute of Technology
Technion City, Haifa, 32000, Israel

Email: moses@ee.technion.ac.il