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Routing Key Chain YANG Data Model
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Abstract

This document describes the key chain YANG data model. A key chain is a list of elements each containing a key, send lifetime, accept lifetime, and algorithm (authentication or encryption). By properly overlapping the send and accept lifetimes of multiple key chain elements, keys and algorithms may be gracefully updated. By representing them in a YANG data model, key distribution can be automated. Key chains are commonly used for routing protocol authentication and other applications. In some applications, the protocols do not use the key chain element key directly, but rather a key derivation function is used to derive a short-lived key from the key chain element key (e.g., the Master Keys used in the TCP Authentication Option).

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[1.](#) Introduction

This document describes the key chain YANG data model. A key chain is a list of elements each containing a key, send lifetime, accept lifetime, and algorithm (authentication or encryption). By properly overlapping the send and accept lifetimes of multiple key chain

elements, keys and algorithms may be gracefully updated. By representing them in a YANG data model, key distribution can be automated. Key chains are commonly used for routing protocol authentication and other applications. In some applications, the protocols do not use the key chain element key directly, but rather a key derivation function is used to derive a short-lived key from the key chain element key (e.g., the Master Keys used in [\[TCP-AO\]](#)).

[1.1.](#) Requirements Notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [\[RFC-KEYWORDS\]](#).

[1.2.](#) Tree Diagrams

A simplified graphical representation of the complete data tree is presented in [Section 3.3](#). The following tree notation is used.

- o Brackets "[" and "]" enclose list keys.
- o Curly braces "{" and "}" contain names of optional features that make the corresponding node conditional.
- o Abbreviations before data node names: "rw" means configuration (read-write), "ro" state data (read-only), "-x" RPC operations, and "-n" notifications.
- o Symbols after data node names: "?" means an optional node, "!" a container with presence, and "*" denotes a "list" or "leaf-list".
- o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- o Ellipsis ("...") stands for contents of subtrees that are not shown.

[2.](#) Problem Statement

This document describes a YANG [\[YANG\]](#) data model for key chains. Key chains have been implemented and deployed by a large percentage of network equipment vendors. Providing a standard YANG model will facilitate automated key distribution and non-disruptive key rollover. This will aid in tightening the security of the core routing infrastructure as recommended in [\[IAB-REPORT\]](#).

A key chain is a list containing one or more elements containing a Key ID, key, send/accept lifetimes, and the associated authentication or encryption algorithm. A key chain can be used by any service or application requiring authentication or encryption. In essence, the key-chain is a reusable key policy that can be referenced wherever it is required. The key-chain construct has been implemented by most networking vendors and deployed in many networks.

A conceptual representation of a crypto key table is described in [\[CRYPTO-KEYTABLE\]](#). The crypto key table also includes keys as well as their corresponding lifetimes and algorithms. Additionally, the key table includes key selection criteria and envisions a deployment model where the details of the applications or services requiring authentication or encryption permeate into the key database. The YANG key-chain model described herein doesn't include key selection criteria or support this deployment model. At the same time, it does not preclude it. The draft [\[YANG-CRYPTO-KEYTABLE\]](#) describes augmentations to the key chain YANG model in support of key selection criteria.

[2.1.](#) Applicability

Other YANG modules may reference ietf-key-chain YANG module key-chain names for authentication and encryption applications. A YANG type has been provided to facilitate reference to the key-chain name without having to specify the complete YANG XML Path Language (XPath) selector.

[2.2.](#) Graceful Key Rollover using Key Chains

Key chains may be used to gracefully update the key and/or algorithm used by an application for authentication or encryption. This MAY be accomplished by accepting all the keys that have a valid accept lifetime and sending the key with the most recent send lifetime. One scenario for facilitating key rollover is to:

1. Distribute a key chain with a new key to all the routers or other network devices in the domain of that key chain. The new key's accept lifetime should be such that it is accepted during the key rollover period. The send lifetime should be a time in the future when it can be assured that all the routers in the domain of that key are upgraded. This will have no immediate impact on the keys used for transmission.
2. Assure that all the network devices have been updated with the updated key chain and that their system times are roughly synchronized. The system times of devices within an administrative domain are commonly synchronized (e.g., using

Network Time Protocol (NTP) [[NTP-PROTO](#)]). This also may be automated.

3. When the send lifetime of the new key becomes valid, the network devices within the domain of key chain will start sending the new key.
4. At some point in the future, a new key chain with the old key removed may be distributed to the network devices within the domain of the key chain. However, this may be deferred until the next key rollover. If this is done, the key chain will always include two keys; either the current and future key (during key rollovers) or the current and previous keys (between key rollovers).

3. Design of the Key Chain Model

The ietf-key-chain module contains a list of one or more keys indexed by a Key ID. For some applications (e.g., OSPFv3 [[OSPFV3-AUTH](#)]), the Key ID is used to identify the key chain entry to be used. In addition to the Key ID, each key chain entry includes a key-string and a cryptographic algorithm. Optionally, the key chain entries include send/accept lifetimes. If the send/accept lifetime is unspecified, the key is always considered valid.

Note that asymmetric keys, i.e., a different key value used for transmission versus acceptance, may be supported with multiple key chain elements where the accept-lifetime or send-lifetime is not valid (e.g., has an end-time equal to the start-time).

Due to the differences in key chain implementations across various vendors, some of the data elements are optional. Finally, the crypto algorithm identities are provided for reuse when configuring legacy authentication and encryption not using key-chains.

A key-chain is identified by a unique name within the scope of the network device. The "key-chain-ref" typedef SHOULD be used by other YANG modules when they need to reference a configured key-chain.

3.1. Key Chain Operational State

The key chain operational state is maintained in a separate tree. The key string itself is omitted from the operational state to minimize visibility similar to what was done with keys in SNMP MIBs. The timestamp of the last key-chain modification is also maintained in the operational state. Additionally, the operational state includes an indication of whether or not a key chain entry is valid for sending or acceptance.

3.2. Key Chain Model Features

Features are used to handle differences between vendor implementations. For example, not all vendors support configuration an acceptance tolerance or configuration of key strings in hexadecimal. They are also used to support of security requirements (e.g., TCP-AO Algorithms [[TCP-AO-ALGORITHMS](#)]) not implemented by vendors or only a single vendor.

3.3. Key Chain Model Tree

```

+--rw key-chains
| +--rw key-chain* [name]
| | +--rw name                string
| | +--rw description?        string
| | +--rw accept-tolerance {accept-tolerance}?
| | | +--rw duration?         uint32
| | +--rw key-entry* [key-id]
| | | +--rw key-id            uint64
| | | +--rw lifetime
| | | | +--rw (lifetime)?
| | | | | +--:(send-and-accept-lifetime)
| | | | | | +--rw send-accept-lifetime
| | | | | | | +--rw (lifetime)?
| | | | | | | +--:(always)
| | | | | | | | +--rw always?                empty
| | | | | | | +--:(start-end-time)
| | | | | | | +--rw start-date-time?         yang:date-and-time
| | | | | | | +--rw (end-time)?
| | | | | | | +--:(infinite)
| | | | | | | | +--rw no-end-time?            empty
| | | | | | | +--:(duration)
| | | | | | | | +--rw duration?                uint32
| | | | | | | +--:(end-date-time)
| | | | | | | +--rw end-date-time?
| | | | | | | | yang:date-and-time
| | | | | +--:(independent-send-accept-lifetime)
| | | | | | {independent-send-accept-lifetime}?
| | | | +--rw send-lifetime
| | | | | +--rw (lifetime)?
| | | | | | +--:(always)
| | | | | | | +--rw always?                empty
| | | | | | +--:(start-end-time)
| | | | | | +--rw start-date-time?         yang:date-and-time
| | | | | | +--rw (end-time)?
| | | | | | | +--:(infinite)
| | | | | | | | +--rw no-end-time?            empty
| | | | | | | +--:(duration)

```



```

| | | | | +-rw duration? uint32
| | | | | +--:(end-date-time)
| | | | | +-rw end-date-time?
| | | | | yang:date-and-time
| | | +-rw accept-lifetime
| | | +-rw (lifetime)?
| | | +--:(always)
| | | | +-rw always? empty
| | | +--:(start-end-time)
| | | +-rw start-date-time? yang:date-and-time
| | | +-rw (end-time)?
| | | +--:(infinite)
| | | | +-rw no-end-time? empty
| | | +--:(duration)
| | | | +-rw duration? uint32
| | | +--:(end-date-time)
| | | +-rw end-date-time?
| | | yang:date-and-time
| | +-rw crypto-algorithm identityref
| | +-rw key-string
| | +-rw (key-string-style)?
| | +--:(keystring)
| | | +-rw keystring? string
| | +--:(hexadecimal) {hex-key-string}?
| | +-rw hexadecimal-string? yang:hex-string
| +-rw aes-key-wrap {aes-key-wrap}?
| +-rw enable? boolean
+--ro key-chains-state
+--ro key-chain-state* [name]
| +-ro name string
| +-ro description? string
| +-ro accept-tolerance {accept-tolerance}?
| | +-ro duration? uint32
| +-ro last-modified-timestamp? yang:date-and-time
| +-ro key-entry-state* [key-id]
| +-ro key-id uint64
| +-ro lifetime
| | +-ro (lifetime)?
| | +--:(send-and-accept-lifetime)
| | | +-ro send-accept-lifetime
| | | +-ro (lifetime)?
| | | +--:(always)
| | | | +-ro always? empty
| | | +--:(start-end-time)
| | | +-ro start-date-time? yang:date-and-time
| | | +-ro (end-time)?
| | | +--:(infinite)
| | | | +-ro no-end-time? empty

```



```

|         |         |         +---:(duration)
|         |         |         | +--ro duration?          uint32
|         |         |         +---:(end-date-time)
|         |         |         +--ro end-date-time?
|         |         |         yang:date-and-time
|         | +---:(independent-send-accept-lifetime)
|         |         | {independent-send-accept-lifetime}?
|         |         +--ro send-lifetime
|         |         | +--ro (lifetime)?
|         |         |         +---:(always)
|         |         |         | +--ro always?            empty
|         |         |         +---:(start-end-time)
|         |         |         +--ro start-date-time?      yang:date-and-time
|         |         |         +--ro (end-time)?
|         |         |         +---:(infinite)
|         |         |         | +--ro no-end-time?        empty
|         |         |         +---:(duration)
|         |         |         | +--ro duration?          uint32
|         |         |         +---:(end-date-time)
|         |         |         +--ro end-date-time?
|         |         |         yang:date-and-time
|         |         +--ro accept-lifetime
|         |         +--ro (lifetime)?
|         |         +---:(always)
|         |         | +--ro always?            empty
|         |         +---:(start-end-time)
|         |         +--ro start-date-time?      yang:date-and-time
|         |         +--ro (end-time)?
|         |         +---:(infinite)
|         |         | +--ro no-end-time?        empty
|         |         +---:(duration)
|         |         | +--ro duration?          uint32
|         |         +---:(end-date-time)
|         |         +--ro end-date-time?
|         |         yang:date-and-time
| +---ro crypto-algorithm      identityref
| +---ro key-string
| | +--ro (key-string-style)?
| | | +---:(keystring)
| | | | +--ro keystring?        string
| | | +---:(hexadecimal) {hex-key-string}?
| | | +--ro hexadecimal-string? yang:hex-string
| +---ro send-lifetime-active?  boolean
| +---ro accept-lifetime-active? boolean
+---ro aes-key-wrap {aes-key-wrap}?
+--ro enable?    boolean

```


4. Key Chain YANG Model

```
<CODE BEGINS> file "ietf-key-chain@2017-02-15.yang"
module ietf-key-chain {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-key-chain";
  prefix key-chain;

  import ietf-yang-types {
    prefix yang;
  }
  import ietf-netconf-acm {
    prefix nacm;
  }

  organization
    "IETF RTG (Routing) Working Group";
  contact
    "Acee Lindem - acee@cisco.com";
  description
    "This YANG module defines the generic configuration
    data for key-chain. It is intended that the module
    will be extended by vendors to define vendor-specific
    key-chain configuration parameters.

    Copyright (c) 2015 IETF Trust and the persons identified as
    authors of the code. All rights reserved.

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    set forth in Section 4.c of the IETF Trust's Legal Provisions
    Relating to IETF Documents
    (http://trustee.ietf.org/license-info).
    This version of this YANG module is part of RFC XXXX; see
    the RFC itself for full legal notices.";

  revision 2017-02-15 {
    description
      "Replace choice statement with identity for crypto-algorithm.
      Removed unneeded groupings.
      Fixed indenations.";
    reference "RFC XXXX: A YANG Data Model for key-chain";
  }

  feature hex-key-string {
    description
      "Support hexadecimal key string.";
```



```
}

feature accept-tolerance {
  description
    "To specify the tolerance or acceptance limit.";
}

feature independent-send-accept-lifetime {
  description
    "Support for independent send and accept key lifetimes.";
}

feature crypto-hmac-sha-1-12 {
  description
    "Support for TCP HMAC-SHA-1 12 byte digest hack.";
}

feature clear-text {
  description
    "Support for clear-text algorithm. Usage is
    NOT RECOMMENDED.";
}

feature aes-cmac-prf-128 {
  description
    "Support for AES Cipher based Message Authentication
    Code Pseudo Random Function.";
}

feature aes-key-wrap {
  description
    "Support for Advanced Encryption Standard (AES) Key Wrap.";
}

feature replay-protection-only {
  description
    "Provide replay-protection without any authentication
    as required by protocols such as Bidirectional
    Forwarding Detection (BFD).";
}

identity crypto-algorithm {
  description
    "Base identity of cryptographic algorithm options.";
}

identity hmac-sha-1-12 {
  base crypto-algorithm;
```



```
    if-feature "crypto-hmac-sha-1-12";
    description
      "The HMAC-SHA1-12 algorithm.";
  }

  identity aes-cmac-prf-128 {
    base crypto-algorithm;
    if-feature "aes-cmac-prf-128";
    description
      "The AES-CMAC-PRF-128 algorithm - required by
       RFC 5926 for TCP-AO key derivation functions.";
  }

  identity md5 {
    base crypto-algorithm;
    description
      "The MD5 algorithm.";
  }

  identity sha-1 {
    base crypto-algorithm;
    description
      "The SHA-1 algorithm.";
  }

  identity hmac-sha-1 {
    base crypto-algorithm;
    description
      "HMAC-SHA-1 authentication algorithm.";
  }

  identity hmac-sha-256 {
    base crypto-algorithm;
    description
      "HMAC-SHA-256 authentication algorithm.";
  }

  identity hmac-sha-384 {
    base crypto-algorithm;
    description
      "HMAC-SHA-384 authentication algorithm.";
  }

  identity hmac-sha-512 {
    base crypto-algorithm;
    description
      "HMAC-SHA-512 authentication algorithm.";
  }
}
```



```
identity clear-text {
  base crypto-algorithm;
  if-feature "clear-text";
  description
    "Clear text.";
}

identity replay-protection-only {
  base crypto-algorithm;
  if-feature "replay-protection-only";
  description
    "Provide replay-protection without any authentication as
    required by protocols such as Bidirectional Forwarding
    Detection (BFD).";
}

typedef key-chain-ref {
  type leafref {
    path
      "/key-chain:key-chains/key-chain:key-chain/key-chain:name";
  }
  description
    "This type is used by data models that need to reference
    configured key-chains.";
}

grouping lifetime {
  description
    "Key lifetime specification.";
  choice lifetime {
    default "always";
    description
      "Options for specifying key accept or send lifetimes";
    case always {
      leaf always {
        type empty;
        description
          "Indicates key lifetime is always valid.";
      }
    }
    case start-end-time {
      leaf start-date-time {
        type yang:date-and-time;
        description
          "Start time.";
      }
      choice end-time {
        default "infinite";
      }
    }
  }
}
```



```
    description
      "End-time setting.";
    case infinite {
      leaf no-end-time {
        type empty;
        description
          "Indicates key lifetime end-time in infinite.";
      }
    }
    case duration {
      leaf duration {
        type uint32 {
          range "1..2147483646";
        }
        units "seconds";
        description
          "Key lifetime duration, in seconds";
      }
    }
    case end-date-time {
      leaf end-date-time {
        type yang:date-and-time;
        description
          "End time.";
      }
    }
  }
}
}
}

grouping key-common-entry {
  description
    "Key-chain entry data nodes common to
    configuration and state.";
  container lifetime {
    description
      "Specify a key's lifetime.";
    choice lifetime {
      description
        "Options for specification of send and accept lifetimes.";
      case send-and-accept-lifetime {
        description
          "Send and accept key have the same lifetime.";
        container send-accept-lifetime {
          description
            "Single lifetime specification for both
            send and accept lifetimes.";
        }
      }
    }
  }
}
```



```
        uses lifetime;
    }
}
case independent-send-accept-lifetime {
    if-feature "independent-send-accept-lifetime";
    description
        "Independent send and accept key lifetimes.";
    container send-lifetime {
        description
            "Separate lifetime specification for send lifetime.";
        uses lifetime;
    }
    container accept-lifetime {
        description
            "Separate lifetime specification for accept lifetime.";
        uses lifetime;
    }
}
}
}
leaf crypto-algorithm {
    type identityref {
        base crypto-algorithm;
    }
    mandatory true;
    description
        "Cryptographic algorithm associated with key.";
}
container key-string {
    description
        "The key string.";
    nacm:default-deny-all;
    choice key-string-style {
        description
            "Key string styles";
        case keystack {
            leaf keystack {
                type string;
                description
                    "Key string in ASCII format.";
            }
        }
    }
    case hexadecimal {
        if-feature "hex-key-string";
        leaf hexadecimal-string {
            type yang:hex-string;
            description
                "Key in hexadecimal string format. When compared
```


to ASCII, specification in hexadecimal affords greater key entropy with the same number of octets. Additionally, it discourages usage of well-known words or numbers.";

```
    }
  }
}
}
}

grouping key-state-entry {
  description
    "Key state entry.";
  uses key-common-entry;
  leaf send-lifetime-active {
    type boolean;
    config false;
    description
      "Indicates if the send lifetime of the
       key-chain entry is currently active.";
  }
  leaf accept-lifetime-active {
    type boolean;
    config false;
    description
      "Indicates if the accept lifetime of the
       key-chain entry is currently active.";
  }
}

grouping key-chain-common {
  description
    "key-chain common grouping.";
  leaf name {
    type string;
    description
      "Name of the key-chain.";
  }
  leaf description {
    type string;
    description
      "A description of the key-chain";
  }
  container accept-tolerance {
    if-feature "accept-tolerance";
    description
      "Tolerance for key lifetime acceptance (seconds).";
    leaf duration {
```



```
        type uint32;
        units "seconds";
        default "0";
        description
            "Tolerance range, in seconds.";
    }
}

grouping key-chain-config {
    description
        "key-chain configuration grouping.";
    uses key-chain-common;
    list key-entry {
        key "key-id";
        description
            "One key.";
        leaf key-id {
            type uint64;
            description
                "Key ID.";
        }
        uses key-common-entry;
    }
}

grouping key-chain-state {
    description
        "key-chain state grouping.";
    uses key-chain-common;
    leaf last-modified-timestamp {
        type yang:date-and-time;
        description
            "Timestamp of the most recent update to the key-chain";
    }
    list key-entry-state {
        key "key-id";
        description
            "One key.";
        leaf key-id {
            type uint64;
            description
                "Key ID.";
        }
        uses key-state-entry;
    }
}
```



```
container key-chains {
  description
    "All configured key-chains on the device.";
  list key-chain {
    key "name";
    description
      "List of key-chains.";
    uses key-chain-config;
  }
  container aes-key-wrap {
    if-feature "aes-key-wrap";
    description
      "AES Key Wrap password encryption.";
    leaf enable {
      type boolean;
      default "false";
      description
        "Enable AES Key Wrap encryption.";
    }
  }
}
container key-chains-state {
  config false;
  description
    "State for all configured key-chains on the device.";
  list key-chain-state {
    key "name";
    description
      "List of key-chains and operational state.";
    uses key-chain-state;
  }
  container aes-key-wrap {
    if-feature "aes-key-wrap";
    description
      "AES Key Wrap password encryption.";
    leaf enable {
      type boolean;
      description
        "Indicates whether AES Key Wrap encryption is enabled.";
    }
  }
}
}
<CODE ENDS>
```


5. Security Considerations

This document enables the automated distribution of industry standard key chains using the NETCONF [\[NETCONF\]](#) protocol. As such, the security considerations for the NETCONF protocol are applicable. The NETCONF protocol mandates confidentiality (section 2.2 of [\[NETCONF\]](#)). Similarly, the RESTCONF protocol also mandates confidentiality (section 1.1 of [\[RESTCONF\]](#)). If a transport not mandating confidentiality is used, it is RECOMMENDED that the transport communication channel be encrypted.

When configured, the key-strings can be encrypted using the AES Key Wrap algorithm [\[AES-KEY-WRAP\]](#). The AES key-encryption key (KEK) is not included in the YANG model and must be set or derived independent of key-chain configuration.

The key strings are not accessible by default and NETCONF Access Control Mode [\[NETCONF-ACM\]](#) rules are required to configure or retrieve them.

The clear-text algorithm is included as a YANG feature. Usage is NOT RECOMMENDED except in cases where the application and device have no other alternative (e.g., a legacy network device that must authenticate packets at intervals of 10 milliseconds or less for many peers using Bidirectional Forwarding Detection [\[BFD\]](#)). Keys used with the clear-text algorithm are considered insecure and SHOULD NOT be reused with more secure algorithms.

It is RECOMMENDED that keys be encrypted or otherwise obfuscated when stored internally on a network device supporting this specification.

6. IANA Considerations

This document registers a URI in the IETF XML registry [\[XML-REGISTRY\]](#). Following the format in [\[XML-REGISTRY\]](#), the following registration is requested to be made:

URI: urn:ietf:params:xml:ns:yang:ietf-key-chain

Registrant Contact: The IESG.

XML: N/A, the requested URI is an XML namespace.

This document registers a YANG module in the YANG Module Names registry [\[YANG\]](#).

name: ietf-key-chain namespace: urn:ietf:params:xml:ns:yang:ietf-key-chain prefix: ietf-key-chain reference: RFC XXXX

[7. References](#)

[7.1. Normative References](#)

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[7.2. Informative References](#)

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[Appendix A](#). Examples

[A.1](#). Simple Key Chain with Always Valid Single Key

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <key-chains xmlns="urn:ietf:params:xml:ns:yang:ietf-key-chain">
    <key-chain>
      <name>keychain-no-end-time</name>
      <description>
        A key chain with a single key that is always valid for tx/rx
      </description>
      <key-entry>
        <key-id>100</key-id>
        <lifetime>
          <send-accept-lifetime>
            <always/>
          </send-accept-lifetime>
        </lifetime>
        <crypto-algorithm>md5</crypto-algorithm>
        <key-string>
          <keystring>keystring_in_ascii_100</keystring>
        </key-string>
      </key-entry>
    </key-chain>
  </key-chains>
</data>
```


[A.2.](#) Key Chain with Keys having Different Lifetimes

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <key-chains xmlns="urn:ietf:params:xml:ns:yang:ietf-key-chain">
    <key-chain>
      <name>keychain2</name>
      <description>
        A key chain where each key contains different send time
        and accept time
      </description>
      <key-entry>
        <key-id>35</key-id>
        <lifetime>
          <send-lifetime>
            <start-date-time>2017-01-01T00:00:00Z</start-date-time>
            <end-date-time>2017-02-01T00:00:00Z</end-date-time>
          </send-lifetime>
          <accept-lifetime>
            <start-date-time>2016-12-31T23:59:55Z</start-date-time>
            <end-date-time>2017-02-01T00:00:05Z</end-date-time>
          </accept-lifetime>
        </lifetime>
        <crypto-algorithm>hmac-sha-1</crypto-algorithm>
        <key-string>
          <keystring>keystring_in_ascii_35</keystring>
        </key-string>
      </key-entry>
      <key-entry>
        <key-id>36</key-id>
        <lifetime>
          <send-lifetime>
            <start-date-time>2017-02-01T00:00:00Z</start-date-time>
            <end-date-time>2017-03-01T00:00:00Z</end-date-time>
          </send-lifetime>
          <accept-lifetime>
            <start-date-time>2017-01-31T23:59:55Z</start-date-time>
            <end-date-time>2017-03-01T00:00:05Z</end-date-time>
          </accept-lifetime>
        </lifetime>
        <crypto-algorithm>hmac-sha-1</crypto-algorithm>
        <key-string>
          <hexadecimal-string>fe:ed:be:af:36</hexadecimal-string>
        </key-string>
      </key-entry>
    </key-chain>
  </key-chains>
</data>
```


A.3. Key Chain with Independent Send and Accept Lifetimes

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <key-chains xmlns="urn:ietf:params:xml:ns:yang:ietf-key-chain">
    <key-chain>
      <name>keychain2</name>
      <description>
        A key chain where each key contains different send time
        and accept time
      </description>
      <key-entry>
        <key-id>35</key-id>
        <lifetime>
          <send-lifetime>
            <start-date-time>2017-01-01T00:00:00Z</start-date-time>
            <end-date-time>2017-02-01T00:00:00Z</end-date-time>
          </send-lifetime>
          <accept-lifetime>
            <start-date-time>2016-12-31T23:59:55Z</start-date-time>
            <end-date-time>2017-02-01T00:00:05Z</end-date-time>
          </accept-lifetime>
        </lifetime>
        <crypto-algorithm>hmac-sha-1</crypto-algorithm>
        <key-string>
          <keystring>keystring_in_ascii_35</keystring>
        </key-string>
      </key-entry>
      <key-entry>
        <key-id>36</key-id>
        <lifetime>
          <send-lifetime>
            <start-date-time>2017-02-01T00:00:00Z</start-date-time>
            <end-date-time>2017-03-01T00:00:00Z</end-date-time>
          </send-lifetime>
          <accept-lifetime>
            <start-date-time>2017-01-31T23:59:55Z</start-date-time>
            <end-date-time>2017-03-01T00:00:05Z</end-date-time>
          </accept-lifetime>
        </lifetime>
        <crypto-algorithm>hmac-sha-1</crypto-algorithm>
        <key-string>
          <hexadecimal-string>fe:ed:be:af:36</hexadecimal-string>
        </key-string>
      </key-entry>
    </key-chain>
  </key-chains>
</data>
```


[Appendix B](#). Acknowledgments

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