A YANG Data Model for Network Interconnect Tester Management
draft-vassilev-bmwg-network-interconnect-tester-02

Abstract

This document introduces new YANG model for use in network interconnect testing containing modules for traffic generator and traffic analyzer.

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1. Introduction

There is a need for standard mechanism to allow the specification and implementation of the transactions part of network tests. The mechanism should allow the control and monitoring of the data plane traffic in a transactional way. This document defines YANG modules for test traffic generator, analyzer and internal interface loopback.

1.1. Terminology

The keywords "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 BCP 14, [RFC2119].

1.1.1. Definitions and Acronyms

DUT: Device Under Test

TA: Traffic Analyzer

TG: Traffic Generator
1.1.2. Tree Diagram

For a reference to the annotations used in tree diagrams included in this draft, please see YANG Tree Diagrams [RFC8340].

1.2. Problem Statement

Network interconnect tests require active network elements part of the tested network that generate test traffic and network elements that analyze the test traffic at one or more points of its path. A network interconnect tester is a device that can either generate test traffic, analyze test traffic or both. Here is a figure borrowed from [RFC2544] representing the horseshoe test setup topology consisting of a single tester and a single DUT connected in a network interconnect loop.

```
+------------+
|            |
+------------|  tester    |<-------------+
|            |            |              |
+------------+              |
|            +------------+              |
|                                        |
|            +------------+              |
|            |            |              |
+----------->|    DUT     |--------------+
|            |
+------------+
```

This document attempts to address the problem of defining YANG model of a network interconnect tester that can be used for development of vendor independent network interconnect tests and utilize the advantages of transactional management using standard protocols like NETCONF.

1.3. Solution

The proposed model splits the design into 3 modules - 1) Traffic Generator module (TG), 2) Traffic Analyzer module (TA). The modules are implemented as augmentations of the ietf-interfaces module adding configuration and state data that models the functionality of a tester. The TA and TG modules concept is illustrated with the following diagram of a tester with two interfaces (named e0 and e1) connected in a loop with single DUT:
2. Using the network interconnect tester model

Basic example of how the model can be used in transactional network test API to control the testers part of a network and report counter statistics and timing measurement data is presented in Appendix A. One of the examples demonstrates the use of the [RFC2544] defined testframe packet.

3. Traffic Generator Module Tree Diagram

module: ietf-traffic-generator
augment /if:interfaces/if:interface:
  +--rw traffic-generator {egress-direction}?
    +--rw (type)?
      +--:(single-stream)
        +--rw frame-size          uint32
        +--rw (frame-data-type)?
          +--:(raw-frame-data)
            +--rw frame-data?   string
        +--rw interframe-gap      uint32
        +--rw interburst-gap?     uint32
        +--rw frames-per-burst?   uint32
        +--rw src-mac-address?    yang:mac-address {ethernet}?
        +--rw dst-mac-address?    yang:mac-address {ethernet}?
        +--rw ether-type?         uint16 {ethernet}?
        +--rw vlan {ethernet-vlan,ethernet}?
          +--rw id                uint16
          +--rw tpid?             uint16
          +--rw pcp?              uint8
          +--rw cfi?              uint8
      +--:(multi-stream)
        +--rw streams
          +--rw stream* [id]
            +--rw id                    uint32
            +--rw frame-size            uint32
++-rw (frame-data-type)?
 | ++-:(raw-frame-data)
 | | ++-rw frame-data? string
++-rw interframe-gap uint32
++-rw interburst-gap? uint32
++-rw frames-per-burst? uint32
++-rw frames-per-stream uint32
++-rw interstream-gap uint32
++-rw src-mac-address? yang:mac-address {ethernet}?
++-rw dst-mac-address? yang:mac-address {ethernet}?
++-rw ether-type? uint16 {ethernet}?
++-rw vlan {ethernet-vlan,ethernet}?
 | ++-rw id uint16
 | ++-rw tpid? uint16
 | ++-rw pcp? uint8
 | ++-rw cfi? uint8
++-rw total-frames? uint64
---rw traffic-generator-ingress {ingress-direction}?
---rw (type)?
 | ---:(single-stream)
 | ----rw frame-size uint32
 | | ----(frame-data-type)?
 | | | ---:(raw-frame-data)
 | | | | ----rw frame-data? string
 | | ----rw interframe-gap uint32
 | | ----rw interburst-gap? uint32
 | | ----rw frames-per-burst? uint32
 | | ----rw src-mac-address? yang:mac-address {ethernet}?
 | | ----rw dst-mac-address? yang:mac-address {ethernet}?
 | | ----rw ether-type? uint16 {ethernet}?
 | | ----rw vlan {ethernet-vlan,ethernet}?
 | | | ++-rw id uint16
 | | | ++-rw tpid? uint16
 | | | ++-rw pcp? uint8
 | | | ++-rw cfi? uint8
 | | ---:(multi-stream)
 | | ----rw streams
 | | | ----rw stream* [id]
 | | | | ++-rw id uint32
 | | | | ++-rw frame-size uint32
 | | | | ----(frame-data-type)?
 | | | | | ---:(raw-frame-data)
 | | | | | | ----rw frame-data? string
 | | | | ----rw interframe-gap uint32
 | | | | ----rw interburst-gap? uint32
 | | | | ----rw frames-per-burst? uint32
 | | | | ----rw frames-per-stream uint32
 | | | | ----rw interstream-gap uint32

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4. Traffic Analyzer Module Tree Diagram

module: ietf-traffic-analyzer

augment /if:interfaces/if:interface:
++rw traffic-analyzer! {ingress-direction}?
| ++rw filter! {filter}?
| | ++rw type identityref
| | ++rw ether-type? uint16
| ++ro state
| | ++ro pkts? yang:counter64
| | ++ro errors? yang:counter64
| | ++ro testframe-stats
| | | ++ro testframe-pkts? yang:counter64
| | | ++ro sequence-errors? yang:counter64
| | | ++ro payload-errors? yang:counter64
| | | ++ro latency
| | | | ++ro samples? uint64
| | | | ++ro min? uint64
| | | | ++ro max? uint64
| | | | ++ro average? uint64
| | | | ++ro latest? uint64
| | ++ro capture {capture}?
| | | ++ro frame* [sequence-number]
| | | | ++ro sequence-number uint64
| | | | ++ro timestamp? yang:date-and-time
| | | | ++ro length? uint32
| | | | ++ro preceding-interframe-gap? uint32
| | | | ++ro data? string
++rw traffic-analyzer-egress! {egress-direction}?
| ++rw filter! {filter}?
| | ++rw type identityref
| ++ro state
| | ++ro pkts? yang:counter64
++--ro errors?        yang:counter64
++--ro testframe-stats
|  ++--ro testframe-pkts?    yang:counter64
|  ++--ro sequence-errors?   yang:counter64
|  ++--ro payload-errors?    yang:counter64
|  ++--ro latency
|     ++--ro samples?      uint64
|     ++--ro min?          uint64
|     ++--ro max?          uint64
|     ++--ro average?      uint64
|     ++--ro latest?       uint64
++--ro capture {capture}?
|  ++--ro frame* [sequence-number]  
|     ++--ro sequence-number      uint64
|     ++--ro timestamp?          yang:date-and-time
|     ++--ro length?             uint32
|     ++--ro preceding-interframe-gap?  uint32
|     ++--ro data?               string
augment /if:interfaces-state/if:interface/if:statistics:
|  ++--ro testframe-pkts?   yang:counter64 {ingress-direction}?
|  ++--ro testframe-sequence-errors?   yang:counter64 {ingress-direction}?
|  ++--ro testframe-payload-errors?   yang:counter64 {ingress-direction}?
augment /if:interfaces-state/if:interface/if:statistics:
|  ++--ro testframe-egress-pkts?   yang:counter64 {egress-direction}?
|  ++--ro testframe-egress-sequence-errors?   yang:counter64 {egress-direction}?
|  ++--ro testframe-egress-payload-errors?   yang:counter64 {egress-direction}?

5. Traffic Generator Module YANG

<CODE BEGINS> file "ietf-traffic-generator@2019-10-08.yang"

module ietf-traffic-generator {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-traffic-generator";
  prefix tg;

  import ietf-interfaces {
    prefix if;
  }
  import ietf-yang-types {
    prefix yang;
  }
  import iana-if-type {
    prefix ianaift;
  }

  organization
    "IETF Benchmarking Methodology Working Group";

This module contains a collection of YANG definitions for description and management of network interconnect testers.

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This version of this YANG module is part of RFC XXXX; see the RFC itself for full legal notices.

revision 2019-10-08 {
  description
    "Initial revision.";
  reference
    "RFC XXXX: Network Interconnect Tester";
}

feature egress-direction {
  description
    "The device can generate traffic in the egress direction.";
}

feature ingress-direction {
  description
    "The device can generate traffic in the ingress direction.";
}

feature multi-stream {
  description
    "The device can generate multi-stream traffic.";
}

feature ethernet {
  description
    "The device can generate ethernet traffic.";
}
feature ethernet-vlan {
  if-feature "ethernet";
  description
    "The device can generate vlan tagged ethernet traffic."
}

grouping traffic-generator-burst-data {
  description
    "Generated traffic burst parameters.";
  leaf frame-size {
    type uint32;
    mandatory true;
    description
      "Size of the frames generated. For example for ethernet interfaces the following definition applies:

      Ethernet frame-size in octets includes:
      * Destination Address (6 octets),
      * Source Address (6 octets),
      * Frame Type (2 octets),
      * Data (min 46 octets or 42 octets + 4 octets 802.1Q tag),
      * CRC Checksum (4 octets).

      Ethernet frame-size does not include:
      * Preamble (dependent on MAC configuration by default 7 octets),
      * Start of frame delimiter (1 octet)

      Minimum standard ethernet frame-size is 64 bytes but generators might support smaller sizes for validation.";
  }
  choice frame-data-type {
    description
      "Choice of frame data type generated.";
    case raw-frame-data {
      leaf frame-data {
        type string {
          pattern '([0-9A-F]{2})*';
        }
        must 'string-length(.)<=(../frame-size*2)';
        description
          "The raw frame data specified as hexadecimal string. The specified data can be shorter than the ../frame-size value specifying only the header or the header and the payload without for example the 4 byte CRC Checksum";
      };
    }
  }
}
in the case of a Ethernet frame."
}
}

leaf interframe-gap {
  type uint32;
  mandatory true;
  description
    "Length of the idle period between generated frames. For example for ethernet interfaces the following definition applies:

    Ethernet interframe-gap between transmission of frames known as the interframe gap (IFG). A brief recovery time between frames allows devices to prepare for reception of the next frame. The minimum interframe gap is 96 bit times (12 octet times) (the time it takes to transmit 96 bits (12 octets) of raw data on the medium). However the preamble (7 octets) and start of frame delimiter (1 octet) are considered a constant gap that should be included in the interframe-gap. Thus the minimum value for standard ethernet transmission should be considered 20 octets.";
}

leaf interburst-gap {
  type uint32;
  description
    "Similar to the interframe-gap but takes place between any two bursts of the stream.";
}

leaf frames-per-burst {
  type uint32;
  description
    "Number of frames contained in a burst";
}

grouping traffic-generator-multi-stream-data {
  description
    "Multi stream traffic generation parameters.";
  container streams {
    description
      "Non-presence container holding the configured stream list.";
    list stream {
      key "id";
      description
        "Each stream repeats a burst until frames-per-stream count is reached followed by interstream-gap delay.";
    }
  }
}
leaf id {
    type uint32;
    description
        "Number specifying the order of the stream.";
}
uses traffic-generator-burst-data;
leaf frames-per-stream {
    type uint32;
    mandatory true;
    description
        "The count of frames to be generated before
         generation of the next stream is started.";
}
leaf interstream-gap {
    type uint32;
    mandatory true;
    description
        "Idle period after the last frame of the last burst.";
}
}
}

grouping ethernet-data {
    description
        "Ethernet frame data specific parameters.";
    reference
        "IEEE 802-2014 Clause 9.2";
    leaf src-mac-address {
        type yang:mac-address;
        description
            "Source Address field of the generated Ethernet packet.";
    }
    leaf dst-mac-address {
        type yang:mac-address;
        description
            "Destination Address field of the generated Ethernet packet.";
    }
    leaf ether-type {
        type uint16;
        description
            "Length/Type field of the generated Ethernet packet.";
    }
    container vlan {
        if-feature "ethernet-vlan";
        description
            "VLAN tag fields.";
    }
    leaf id {

type uint16 {
    range "0..4095";
}
mandatory true;

description
    "VLAN id.";
}
leaf tpid {
    type uint16;
    default "33024";
    description
        "Configures the Tag Protocol Identifier (TPID) of the 802.1q VLAN tag sent. This value is used together with the vlan id for filtering incoming vlan tagged packets.";
}
leaf pcp {
    type uint8 {
        range "0..7";
    }
    default "0";
    description
        "Configures the IEEE 802.1p Priority Code Point (PCP) value of the transmitted 802.1q VLAN tag.";
}
leaf cfi {
    type uint8 {
        range "0..1";
    }
    default "0";
    description
        "Configures the Canonical Format Identifier (CFI) field (shall be 0 for Ethernet switches) of the transmitted 802.1q VLAN tag.";
}

augment "/if:interfaces/if:interface" {
    description
        "Traffic generator augmentations of ietf-interfaces.";
    container traffic-generator {
        if-feature "egress-direction"
        description
            "Traffic generator for egress direction.";
        choice type {
            description
                "Choice of the type of the data model of the generator."
Single or multi stream.

case single-stream {
    uses traffic-generator-burst-data;
}

case multi-stream {
    uses traffic-generator-multi-stream-data;
}

leaf total-frames {
    type uint64;
    description
    "If this leaf is present the stream generation will stop after the specified number of frames are generated."
}

container traffic-generator-ingress {
    if-feature "ingress-direction";
    description
    "Traffic generator for ingress direction.";
    choice type {
        description
        "Choice of the type of the data model of the generator. Single or multi stream."
        case single-stream {
            uses traffic-generator-burst-data;
        }
        case multi-stream {
            uses traffic-generator-multi-stream-data;
        }
    }
    leaf total-frames {
        type uint64;
        description
        "If this leaf is present the stream generation will stop after the specified number of frames are generated."
    }
}

augment "/if:interfaces-state/if:interface/if:statistics" {
    description
    "Counters of generated traffic octets and packets."
    leaf generated-pkts {
        type yang:counter64;
        description
        "Traffic generator packets sent."
    }
    leaf generated-octets {

type yang:counter64;

description
"Traffic generator octets sent."
}

leaf generated-ingress-pkts {
  if-feature "ingress-direction";
  type yang:counter64;
  description
"Traffic generator packets generated in ingress mode.";
}

leaf generated-ingress-octets {
  if-feature "ingress-direction";
  type yang:counter64;
  description
"Traffic generator octets generated in ingress mode.";
}

augment "/if:interfaces/if:interface/tg:traffic-generator/tg:type/"
  + "tg:single-stream" {
    when "derived-from-or-self(../if:type, 'ianaift:ethernetCsmacd')" {
      description
      "Ethernet interface type.";
    }
  if-feature "ethernet";
  description
  "Ethernet specific augmentation for egress single stream generator type.";
  uses ethernet-data;
}

augment "/if:interfaces/if:interface/tg:traffic-generator/tg:type/"
  + "tg:multi-stream/tg:streams/tg:stream" {
    when "derived-from-or-self(../../../if:type, 'ianaift:ethernetCsmacd')" {
      description
      "Ethernet interface type.";
    }
  if-feature "ethernet";
  description
  "Ethernet specific augmentation for egress multi stream generator type.";
  uses ethernet-data;
}

augment "/if:interfaces/if:interface/tg:traffic-generator-ingress/tg:type/"
  + "tg:single-stream" {
    when "derived-from-or-self(../if:type, 'ianaift:ethernetCsmacd')" {
      description
      "Ethernet interface type.";
    }
  if-feature "ethernet";
  description
  "Ethernet specific augmentation for egress single stream generator type.";
  uses ethernet-data;
}
"Ethernet interface type."
}
if-feature "ethernet"

description
  "Ethernet specific augmentation for ingress
  single stream generator type."
uses ethernet-data;
}

augment "'/if:interfaces/if:interface/tg:traffic-generator-ingress/tg:type/"
  + "tg:multi-stream/tg:streams/tg:stream" {
  when "derived-from-or-self(../../../if:type, 'ianaift:ethernetCsmacd')"
  description
    "Ethernet interface type."
}
if-feature "ethernet"

description
  "Ethernet specific augmentation for ingress
  multi stream generator type."
uses ethernet-data;
}

</CODE ENDS>

6. Traffic Analyzer Module YANG

<CODE BEGINS> file "ietf-traffic-analyzer@2019-10-08.yang"

module ietf-traffic-analyzer {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-traffic-analyzer";
  prefix ta;

  import ietf-interfaces {
    prefix if;
  }
  import ietf-yang-types {
    prefix yang;
  }

  organization
    "IETF Benchmarking Methodology Working Group";
  contact
    "WG Web:  <http://tools.ietf.org/wg/bmwg/>
    WG List:  <mailto:bmwg@ietf.org>
    Editor:   Vladimir Vassilev"
<mailto:vladimir@lightside-instruments.com>

description
"This module contains a collection of YANG definitions for
description and management of network interconnect testers.

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This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices."

revision 2019-10-08 {
  description
    "Initial revision.";
  reference
    "RFC XXXX: Network Interconnect Tester";
}

feature egress-direction {
  description
    "The device can analyze traffic from the egress direction.";
}

feature ingress-direction {
  description
    "The device can generate traffic from the ingress direction.";
}

feature filter {
  description
    "This feature indicates that the device implements
    filter that can specify a subset of packets to be
    analyzed when filtering is enabled.";
}

feature capture {
  description
    "This feature indicates that the device implements
    packet capture functionality.";
}
identity filter {
  description
  "Base filter identity.";
}

identity ethernet {
  base ta:filter;
  description
  "Ethernet packet fields filter.";
}

grouping statistics-data {
  description
  "Analyzer statistics.";
  leaf pkts {
    type yang:counter64;
    description
    "Total number of packets analyzed.";
  }
  leaf errors {
    type yang:counter64;
    description
    "Count of packets with errors.
    Not counted in the pkts or captured.
    For example packets with CRC error.";
  }
  container testframe-stats {
    description
    "Statistics for testframe packets containing
    either sequence number, payload checksum,
    timestamp or any combination of these features.";
    leaf testframe-pkts {
      type yang:counter64;
      description
      "Total count of detected testframe packets.";
    }
    leaf sequence-errors {
      type yang:counter64;
      description
      "Total count of testframe packets with
      unexpected sequence number. After each sequence
      error the expected next sequence number is
      updated.";
    }
    leaf payload-errors {
      type yang:counter64;
      description
      "Total count of testframe packets with
      unexpected payload checksum.";
    }
  }
}
payload errors.
}
} container latency {
    description
    "Latency statistics.";
    leaf samples {
        type uint64;
        description
        "Total count of packets used for estimating
        the latency statistics. Ideally
        samples=../testframe-stats.";
    }
    leaf min {
        type uint64;
        units "nanoseconds";
        description
        "Minimum measured latency.";
    }
    leaf max {
        type uint64;
        units "nanoseconds";
        description
        "Maximum measured latency.";
    }
    leaf average {
        type uint64;
        units "nanoseconds";
        description
        "The sum of all sampled latencies divided
        by the number of samples.";
    }
    leaf latest {
        type uint64;
        units "nanoseconds";
        description
        "Latency of the latest sample.";
    }
}
}
}

grouping capture-data {
    description
    "Grouping with statistics and data
    of one or more captured frame.";
    container capture {
        if-feature "capture";
        description
}
"Statistics and data of one or more captured frames."

list frame {
  key "sequence-number";
  description "Statistics and data of a captured frame.";
  leaf sequence-number {
    type uint64;
    description "Incremental counter of frames captured.";
  }
  leaf timestamp {
    type yang:date-and-time;
    description "Timestamp of the moment the frame was captured.";
  }
  leaf length {
    type uint32;
    description "Frame length. Ideally the data captured will be of the same length but can be shorter depending on implementation limitations.";
  }
  leaf preceding-interframe-gap {
    type uint32;
    units "nanoseconds";
    description "Measured delay between the reception of the previous frame was completed and the reception of the current frame was started.";
  }
  leaf data {
    type string {
      pattern '([0-9A-F]{2})*';
    }
    description "Raw data of the captured frame.";
  }
}


grouping filter-data {
  description "Grouping with a filter container specifying the filtering rules for processing only a specific subset of the frames.";
  container filter {
    
    
  }
if-feature "filter";
presence "When present packets are filtered before analyzed according to the filter type";
description "Contains the filtering rules for processing only a specific subset of the frames.";
leaf type {
type identityref {
  base ta:filter;
}
mandatory true;
description "Type of the applied filter. External modules can define alternative filter type identities.";
}
}

augment "/if:interfaces/if:interface" {
description "Traffic analyzer augmentations of ietf-interfaces.";
container traffic-analyzer {
  if-feature "ingress-direction";
presence "Enables the traffic analyzer for ingress traffic.";
description "Traffic analyzer for ingress direction.";
uses filter-data;
container state {
  config false;
description "State data.";
  uses statistics-data;
  uses capture-data;
}
}
container traffic-analyzer-egress {
  if-feature "egress-direction";
presence "Enables the traffic analyzer for egress traffic.";
description "Traffic analyzer for egress direction.";
uses filter-data;
container state {
  config false;
description "State data.";
  uses statistics-data;
  uses capture-data;
}
augment "/if:interfaces/if:interface/ta:traffic-analyzer/ta:filter" {
    when "ta:type = 'ta:ethernet';
    description
        "Ethernet frame specific filter type."
    leaf ether-type {
        type uint16;
        description
            "The Ethernet Type (or Length) value
            defined by IEEE 802.";
        reference
            "IEEE 802-2014 Clause 9.2";
    }
}

augment "/if:interfaces-state/if:interface/if:statistics" {
    if-feature "ingress-direction";
    description
        "Counters implemented by ports with analyzers."
    leaf testframe-pkts {
        type yang:counter64;
        description
            "Testframe packets recognized by the traffic analyzer."
    }
    leaf testframe-sequence-errors {
        type yang:counter64;
        description
            "Testframe packets part of the recognized total
            but with unexpected sequence number."
    }
    leaf testframe-payload-errors {
        type yang:counter64;
        description
            "Testframe packets part of the recognized total
            but with payload errors."
    }
}

augment "/if:interfaces-state/if:interface/if:statistics" {
    if-feature "egress-direction";
    description
        "Counters implemented by ports with egress analyzers."
    leaf testframe-egress-pkts {
        type yang:counter64;
        description
            "Testframe packets recognized by the traffic analyzer."
    }
}
"Testframe egress packets recognized by the traffic analyzer."
}
leaf testframe-egress-sequence-errors {
  type yang:counter64;
  description
    "Testframe egress packets part of the recognized total
    but with unexpected sequence number.";
}
leaf testframe-egress-payload-errors {
  type yang:counter64;
  description
    "Testframe egress packets part of the recognized total
    but with payload errors.";
}
}

<CODE ENDS>

7. IANA Considerations

This document registers three URIs and three YANG modules.

7.1. URI Registration

This document registers three URIs in the IETF XML registry
[RFC3688]. Following the format in RFC 3688, the following
registration is requested to be made:


Registrant Contact: The IESG.

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

7.2. YANG Module Name Registration

This document registers three YANG module in the YANG Module Names
registry YANG [RFC6020].
8. Security Considerations

This document does not introduce any new security concerns in addition to those specified in [RFC7950], section 15.

9. References

9.1. Normative References


9.2. Informative References


Appendix A. Examples

The following topology will be used for the examples in this section:

```
+-------------+          +------------+         +------------+
|             | e0    e0 |            | e1   e0 |            |
| tester0   TG|>-------->|    dut0    |>------->|TA  tester1 |
|             |          |            |         |            |
+-------------+          +------------+         +------------+
```

A.1. Basic Test Program

This program based on transactional network test API shows how the modules can be used:

```python
# Connect to network
net=tntapi.connect("topology.xml")

# Configure DUTs and enable traffic-analyzers
net.node("dut0").edit( 
    "create /interfaces/interface[name='e0'] -- type=ethernetCsmacd"
)
net.node("dut0").edit( 
    "create /interfaces/interface[name='e1'] -- type=ethernetCsmacd"
)
net.node("dut0").edit( 
    "create /flows/flow[id='t0'] -- match/in-port=e0 " 
    "actions/action[order='0']/output-action/out-port=e0"
)
net.node("dut0").edit( 
    "create /interfaces/interface[name='e0']/traffic-analyzer"
)
net.commit()

# Get network state – before
before=net.get()

# Start traffic
net.node("dut0").edit( 
    "create /interfaces/interface[name='e0']/traffic-generator -- " 
    "frame-size=64 interframe-gap=20"
)

net.commit()

time.sleep(60)

# Stop traffic
net.node("dut0").edit("delete /interfaces/interface[name='e0']/" 
    "traffic-generator")
net.commit()
```
# Get network state - after
after=net.get()

# Report
sent_pkts=delta("tester0",before,after,
    "/interfaces/interface[name='e0']/statistics/out-unicast-pkts")

received_pkts=delta("tester1",before,after,
    "/interfaces/interface[name='e0']/statistics/in-unicast-pkts")

latency_max=absolute(after,
    "/interfaces/interface[name='e0']/traffic-analyzer/state/
    "testframe-stats/latency/max")

# Cleanup
net.node("tester1").edit(
    "delete /interfaces/interface/traffic-analyzer")

net.node("dut0").edit("delete /flows")

net.node("dut0").edit("delete /interfaces")

net.commit()

A.2. Generating RFC2544 Testframes

In sec. C.2.6.4 Test Frames a detailed format is specified. The frame-data leaf allows full control over the generated frames payload.

... net.node("tester1").edit(  "merge /interfaces/interface[name='e0']/"
    "traffic-generator -- frame-data="
    "6CA96F0000026CA96F00000108004500"
    "002ED4A500000A115816C0000201C000"
    "0202C0200007001A0000010203040506"
    "0708090A0B0C0D0E0F101112")
...

Author’s Address

Vladimir Vassilev
Lightside Instruments

Email: vladimir@lightside-instruments.com