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TECHNICAL REPORT

**Environmental Engineering (EE);
Testing methodology for equipment able of
dynamic performances adaptation**

ETSI

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Modal verbs terminology

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Executive summary

The present document addresses the issue of testing methodology for equipment and networks able to dynamically adapt performance as function of real need. In the ambit of SDN (Software Defined Networks) equipment performances such as throughput, latency, consumption, etc. may be dynamically optimized as function of real-time traffic load for instance, as an example in order to optimize operational expenditures.

In the assumption that equipment always shows constant performances, today's standardized testing procedures considers only one fixed test configuration, typically at maximum load, or at most very few steady states e.g. 100 %, 50 %, 0 % of traffic load. That is, current testing methodologies do not replicate testing conditions resembling traffic load variations as happens in real life, and equipment performances are not verified and correlated accordingly.

When it comes to Software Defined Networks and equipment able to dynamically adapt performances according to real-time needs, novel measurement methodologies should be developed to properly evaluate and characterize "load cognizant" equipment and networks. Such novel methods should be able to meaningfully resemble real life traffic load shapes, as well as to aggregate and correlate measured data also in coordination with the Network Management System and/or the Equipment Management System, properly testing and characterizing equipment performances proportionality (such as power consumption, throughput, latency, etc.), as well as the response time to States transitions and any other eventual impacts on QoS and/or on Network stability.

As an example, an Energy Aware equipment may operate in a plurality of Power Management Modes according to traffic load, while an Energy Aware Network may adjust traffic routing paths so that, when traffic level is high, higher performances are provided (e.g. an higher number of links are enabled) while when the traffic load level is reduced, performances are proportionally reduced, for instance by merging traffic to a smaller number of links so that other links can run at reduced rate or set in sleeping or power-off modes.

Main scope of this Technical Report is to start building consciousness of this new problematic, to suggest environments and conditions for properly testing such new techniques, paving the way to new series of Standard test methodologies specifically tailored to SDN.

Introduction

Implementing SDN and NFV may be slowed down by lack of proper standardization able to ensure operators that the security, resilience and availability of their networks are not impaired when virtualised network functions, software defined network topologies and/or software defined equipment performances are introduced.

As an example the ability to dynamically adapt power consumption to actual traffic load can become a key feature for the success of Software Defined Networks, by leading to consistent OPEX saving thanks to energy usage optimization while guaranteeing peak load. Whereby, coming generation of communications equipment will be designed to adapt performances and power consumption according to traffic load, while actual standard measurement procedures simply do not consider such conditions and are therefore unsuitable to determines equipment's ability to adapt performances to traffic load needs, i.e. to provide a suitable test and characterization environment for testing the dynamic response of equipment and networks to performances variations requests.

In an environment, communications equipment can operate in more than one power management mode. The power management mode determines the power consumption, and it is properly selected to optimize power consumption to real needs. The testing method herein described is aimed to closely resemble real life traffic load, and measures the response of the communications equipment to the transition event between power management modes triggered by the traffic load variations. One or more parameters can be measured, for example communications equipment performances such as data throughput, latency, loss of rate, as function of dynamic variations in traffic load, as well as characteristics such as transition timing, power consumption, etc.

Measurements taken should corresponds specifically to time periods when the communications equipment is handling the transition between traffic load levels eventually triggering transition between power management modes or other dynamic adaptation functions, or when the communications equipment is in one of the possible steady States which are dependent by the applied traffic load or by any other State transition trigger.

The testing apparatus should also determine the coordination and promptness of the dynamic response, such as for instance the ability to withstand sudden traffic ramping up, e.g. to timely wake-up from a sleeping or power-off State. Thus, the testing equipment determines the direct response of the communications equipment to a transition in level of the trigger event, e.g. traffic load, ultimately determining if the equipment under test guarantee the desired quality of service (QoS) in all the possible working conditions.

1   Scope

The present document addresses the issues of testing methodology for equipment and/or network configurations able to dynamically adapt its performance as function of a generic variable, e.g. traffic load variations, eventually under the control of a local and/or a centralized Management entity. Useful in the ambit of SDN (Software Defined Networks) and/or NFV (Network Function Virtualization) applications where network topology, equipment availability and/or performances such as throughput, latency, power consumption, jitter, etc. may be dynamically adapted as function of real-time needs, in order for instance to optimize operational expenditures.

The present document is intended as a general introduction to the issue in question, with the aim to be the basis for a family of papers dedicated to relevant applications may be developed in the future as part of SDN and/or NFV evolution. For sake of clarity the present document mainly refers to the ability to dynamically adapt power consumption to traffic load variations (hereinafter also called Energy Aware Networking), but principles herein described may be extended to test any other SDN and/or NFV application having the scope of altering network topology or equipment performances as function of a generic variable.

2   References

2.1   Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

Not applicable.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

3   Definitions and abbreviations

3.1   Definitions

For the purposes of the present document, the following terms and definitions apply:

energy consumption: amount of consumed energy

energy efficiency: relation between the useful output and energy consumption

node: physical representation of one or more functions

power consumption: amount of consumed power

power saving feature: feature which contributes to decreasing power consumption compared to the case when the feature is not implemented

system under test: node being measured

test suite: complete sequence of measurements including low, medium, and high load levels as individual test steps

useful output: maximum capacity of the system under test which is depending on the different functions

3.2   Abbreviations

For the purposes of the present document, the following abbreviations apply:

bps	bits per second
CBR	Constant Bit Rate
DCN	Data Control Network
DUT	Device Under Test
IUpp	Interval Unit peak to peak
NE	Network Element
NFV	Network Function Virtualization
NMS	Network Management System
OPEX	OPeration EXpenditure
PMM	Power Management Mode
pps	packets per second
PW	Pseudo Wire
SDN	Software Defined Networks
SW	SoftWare
TDM	Time Division Multiplexing
TLG	Traffic Load Gradient
VBR	Variable Bit Rate

4   Overview

4.0   General

Although the DUT may be viewed principally in terms of its inputs, outputs and transfer characteristics, a certain degree of knowledge of its internal working may be needed due to the dynamic nature of the test. When it comes to SDN and/or NFV application, altering network topology or equipment performances as function of a generic variable such as for instance the traffic load, the testing apparatus may be arranged to determine meaningful performances, quality and/or stability parameters, at the data layer and at the control layer, such as for instance:

- performances in terms of maximum traffic data throughput, burst withstanding capability, latency, jitter, etc. when the device is "stably" in a given (e.g. power-mode) state of the various states available;

- quality and stability parameters such as: packet loss, packets errors, etc. and/or misalignments, loss of connection, etc. both at data and control layers, associated with the transitions from one (e.g. power-mode) state to another.

The testing apparatus may run multiple and coordinated measurements of key indexes when dynamically changing for instance the traffic load. The testing apparatus may be arranged to test for instance power-saving solutions aimed to provide fast and effective flexibility to lower the performances (and e.g. power consumption) of lightly utilized modules.

Indeed two main situations can be envisaged:

- DUT is capable of reducing its performances in real time while doing actual work (e.g. clock scaling).

- DUT is capable of reducing its performances during extended idle periods (no useful work can be done, e.g. no traffic can flow) and may be asleep or turned off. In this case functional degradations may be such as not to allow any direct monitoring of the DUT, but control (e.g. turn on) capability and wake-up time coordination and promptness may be evaluated e.g. in reason to withstand a given sudden traffic ramping up.

The Data Plane of the DUT may be tested for each possible steady-state as well as for each high-to-low (e.g. power mode) state and low-to-high (e.g. power mode) state transition. DUT characterizing parameters (Performance Indexes) may be collected correlated to the state change events trigger (e.g. traffic load), in order to characterize also their dynamics.

The Control Plane of the DUT may be tested as well, as responsible of the (e.g. power-mode) states transition coordination, where it may be deeply involved in critical decisions such as: thresholds setting, execution timing, etc.

4.1 DUT characterizing parameters (Performance Indexes)

Given the dynamic nature of test method herein treated, performance indexes may be collected in correlation to the trigger event in order to get a complete vision in terms of advantages (e.g. energy saving) and/or drawbacks (e.g. packet loss, increased latency, etc.), for a thorough DUT characterization.

As an example, the following indexes can be identified (more may be added depending on the DUT characteristics):

- absolute max data throughput (bit per second or packet per second) and max data throughput (bps or pps) at reduced performances according to selected state (e.g. Power Management Mode: PMM);

- transition time (sec) for entering or exiting a given state (e.g. PMM);

- power consumption (watt) at max performances and power consumption variation (in watt or in %) compared to max performances condition;

- loss rate (bps or pps) and loss rate variation (in bps or pps or in bps/pps %) compared to max performances condition;

- latency (sec) at max performances and latency variation (in sec or in %) compared to max performances condition;

- jitter (IUpp, may be jitter tolerance and/or generated) at max performances and jitter variation (in IUpp or in %) compared to max performances condition;

- any other parameter characterizing the DUT, e.g. computational capability, memory, fans air flow, etc.

Quantitative results (numbers) may be presented in table and/or in graphical form, with some additional note reporting relevant qualitative findings if any (e.g. some revealed instability, etc.). If needed, a more thorough description of some qualitative result may be provided by means of a case study reported in a dedicated paragraph.

4.2 Data Throughput

Test may identify the maximum useful work, e.g. data throughput of the given traffic flow, at any state (e.g. PMM), by determining the highest data throughput showing the count of the offered packets equal to the count of received packets (no packets loss). Per each traffic load step as per par. 4.8 below, CBR traffic (Constant Bit Rate) may be used, or more realistically a VBR (Variable Bit Rate) traffic comprising a rate variation which averages the determined traffic load level by means of bursts of packets.

4.3 Transition Time

States (e.g. PMM) Transition Time may be properly measured, in strict coordination with the given trigger (e.g. traffic load). The entering and exiting time from/to each e.g. PMM to/from next e.g. PMM can be expressed in seconds, and be measured at each possible PMM states, comprising states where traffic flow is not allowed (e.g. sleeping modes).

4.4 Power

Power consumption may be measured in strict coordination with the given traffic load and PMM setting, properly correlated to it, and measured at each of the possible PMM states, comprising states where traffic flow is not allowed (sleeping modes).

4.5   Latency

In the example of an energy-aware systems, power reduction may cause increased latency, for instance when it comes to clock scaling techniques. For this reason, a correct assessment of SDN techniques cannot be done regardless of latency. Latency may be measured as the time delay experienced by each one-way (source to destination) traffic flow, properly correlated to each PMM states where traffic flow is allowed.

4.6   Jitter

In TDM systems (such as for instance PW), jitter (tolerated and/or generated) may be as well influenced by the dynamic performance adaptation technique. Jitter experienced by each one-way (source to destination) traffic flow may be measured and properly correlated to each of the possible PMM states where traffic flow is allowed.

4.7   Traffic Loss and/or instabilities

During the test certain levels of Traffic Loss or some sort of instability may be experienced. Traffic Loss may be measured at each one-way (source to destination) traffic flow, measured at each of the possible PMM states where traffic flow is allowed and properly correlated to for example the given PMM or PMM transition. The DUT should also be monitored for eventual instabilities induced by the transitions such as SW stacking, restart, etc.

Switching from for example different PMM may imply wake-up time and therefore coordination issues may arise, or can induce electrical interferences to adjacent circuits. For these reasons Traffic Loss and instabilities may be monitored also to adjacent cards and/or interfaces (where applicable), both when in states where traffic can flow as well as when no traffic flow is allowed (e.g. sleeping modes).

4.8   Traffic Load Gradient

A new test function is herein introduced to characterize the DUT under the perspective of Dynamic Performance Adaptation to Traffic Load, namely the Traffic Load Gradient (TLG) function of the Traffic Load variation entity and rapidity.

NOTE: Similarly to TLG, other "gradients" may be defined as function of the Dynamic Performance Adaptation trigger of the given DUT (e.g. Ambient Temperature Gradients, Supply Voltage Gradients, Active Subscribers Gradient, etc.).
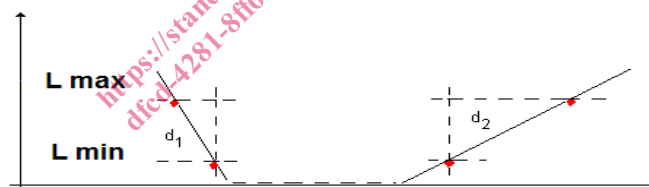

Figure 1: Traffic Load Gradient (L = Traffic Load)

Traffic Load Gradient defines traffic load magnitude (L_{min}, L_{max}) and timing (d_1, d_2) of the transition step.

DUT Performances Indexes may be verified by applying TLG gradients from the traffic load of the given lower PMM up to the minimum to enter the next given higher PMM ($L_{min} \rightarrow L_{max}$; d_2) or from the traffic load of the given higher PMM down to the traffic load to enter the next given lower PMM ($L_{max} \rightarrow L_{min}$; d_1).

Assuming as an example a linear TLG shape having 10 % traffic variation in 10 minutes (according to real traffic test campaigns this may resemble well enough real life dynamics of aggregated traffic), as an approximation it could be well modelled for instance by consecutives 1 % sudden steps and 1min waiting time, according to figure 2.