Control and management of sliceable transponders

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Abstract *This paper presents control and management of sliceable transponders through NETCONF and YANG. Three OAM schemes are also presented and evaluated with simulations: centralized, hierarchical, and a scheme based on pre-instructions. Hierarchical and pre-instruction provide faster reaction time to degradations.*

Introduction

Flexibility requirements of network operators have paved the way to sliceable transponders (S-BVT)[1] enabling multiple independent optical flows and the possibility to choose among several transmission parameters such as modulation formats and coding. Sliceable transponders permit operators to i) optimize network capacity by configuring the transponder to have the most spectrally efficient format for the distance required; ii) re-direct optical flows based on traffic dynamics and requirements; iii) monitor end-to-end service quality of transmission (QoT). Moreover, the needs of such flexibility together with the reduction of system margins[2] are bringing to a tight tie between control and management. Indeed, once a lightpath is configured, it is expected that control system may reconfigure S-BVT parameters (e.g., modulation format) based on monitoring information. The management of monitoring information and alarms requires to be scalable in order to avoid the overloading of controllers and delay transponder reconfiguration. NETCONF is an emerging Software Defined Networking (SDN) protocol since integrating functionalities of control and management[3,4].

This paper presents control and management of sliceable transponders through NETCONF protocol. A YANG model for NETCONF is detailed highlighting *configuration* and *state* parameters for the transponder. Moreover, three schemes for Operation Administration and Maintenance (OAM) are presented: *centralized*, *hierarchical*, and *pre-programmed*. The schemes are compared through simulations in terms of reconfiguration delay.

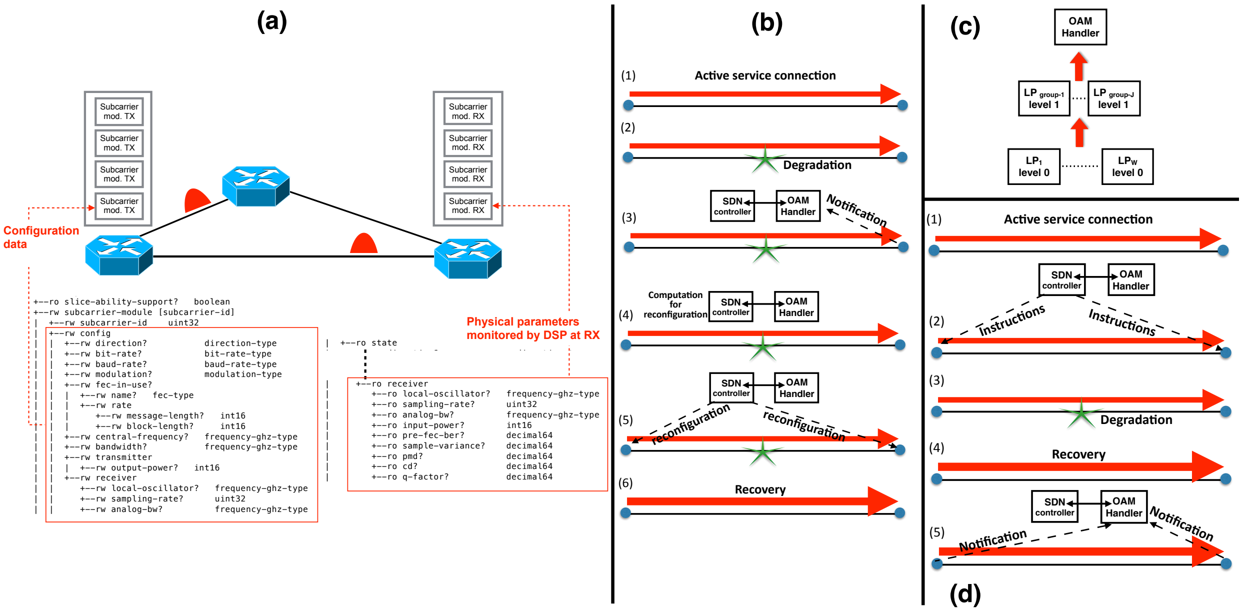
Control and management of sliceable transponders with NETCONF

The S-BVT architecture proposed in[1] is assumed. We derive control and management tasks from the IETF Application-Based Network Operations (ABNO) architecture[5]. In particular, an SDN controller is responsible for control tasks, while the OAM Handler for management tasks of OAM. Control tasks for S-BVT include: retrieval of capabilities (e.g., the maximum bit-rate supported by the S-BVT), transponder configuration, transponder reconfiguration for survivability purposes. Management tasks of S-BVT include: configuration of threshold parameters generating alarms (e.g., if Q-factor is below the threshold an alarm is generated), end-to-end monitoring of service, correlation and processing of monitoring information, and triggering actions to preserve or recover, thus maintain, the affected services.

NETCONF protocol supports the aforementioned tasks. In particular, the retrieval of S-BVT capabilities can be done with the `<get>` message, while (re)configuration with `<edit-config>` message. The configuration of threshold parameters generating alarms can be done with the `<create-subscription>` message, while alarms can be implemented with `<notification>` message. End-to-end monitoring is done through digital signal processing (DSP) modules in the S-BVT, whereas correlation of monitoring information and service mantainance is performed by management entities such as the ABNO OAM Handler[5].

YANG model for control and management

Transponder parameters are modeled with YANG and are included into NETCONF messages. The YANG model presented in[4] is here considered and the related tree is shown in Fig. 1a. The YANG model is organized per sub-carrier module. As configuration data (i.e., configurable parameters), some data has to be specified both in transmission and detection (e.g., baudrate, bit rate, modulation format, FEC). Then, different data is present if the "direction" is in transmission or detection: e.g., local oscillator configuration of the receiver or output power at the transmitter. Re-



```
+--ro slice-ability-support?   boolean
+--rw subcarrier-module [subcarrier-id]
|  +--rw subcarrier-id    uint32
|  +--rw config
|  |  +--rw direction?            direction-type
|  |  +--rw bit-rate?             bit-rate-type
|  |  +--rw baud-rate?            baud-rate-type
|  |  +--rw modulation?           modulation-type
|  |  +--rw fec-in-use?
|  |  |  +--rw name?   fec-type
|  |  |  +--rw rate
|  |  |     +--rw message-length?   int16
|  |  |     +--rw block-length?     int16
|  |  +--rw central-frequency?   frequency-ghz-type
|  |  +--rw bandwidth?           frequency-ghz-type
|  |  +--rw transmitter
|  |  |  +--rw output-power?   int16
|  |  +--rw receiver
|  |     +--rw local-oscillator?   frequency-ghz-type
|  |     +--rw sampling-rate?      uint32
|  |     +--rw analog-bw?          frequency-ghz-type
```

```
|  +--ro state

|     +--ro receiver
|        +--ro local-oscillator?   frequency-ghz-type
|        +--ro sampling-rate?      uint32
|        +--ro analog-bw?          frequency-ghz-type
|        +--ro input-power?        int16
|        +--ro pre-fec-ber?        decimal64
|        +--ro sample-variance?    decimal64
|        +--ro pmd?                decimal64
|        +--ro cd?                 decimal64
|        +--ro q-factor?           decimal64
```

Fig. 1: YANG model to control and manage S-BVT (a); centralized OAM (b); hierarchical OAM (c); pre-programmed (d).

garding central frequency and local oscillator, we defined the type “frequency-ghz-type” to discern between the central frequency of a sub-carrier and of a media-channel: the central frequency of a media-channel has to follow ITU-T specifications in steps of 6.25 GHz, thus can be expressed as just an integer number, while the central frequency of a sub-carrier of a media-channel composed by several sub-carriers does not necessary follow a grid. Regarding state data (i.e., only readable data such as monitoring parameters), first, configuration data is replicated into state data to enable an operator to verify the actual configuration of the transponder (not shown in the figure). Then, other state data include monitored parameters as pre-FEC BER, Q-factor, chromatic dispersion (CD), and polarization mode dispersion (PMD), e.g. expressed as “decimal64”.

Management schemes and reconfiguration

In this section, three different OAM schemes are considered to process monitoring information and maintain the service.

- **Centralized** (Fig. 1b): the OAM Handler receives and processes all the alarms (e.g., for failure localization) and, for each connection, triggers the SDN-controller to preserve the service if needed. Then, the SDN-controller performs computations (e.g., FEC) to re-configure S-BVT. Finally, S-BVT is reconfigured and connection recovered.
- **Hierarchical** (Fig. 1c): each entity in the hierarchy provides the same functions of the OAM Handler (i.e., collecting and correlating alerts and triggering actions to preserve services) but is responsible for a subset of lightpaths (LPs), thus it process alarms only for this subset[6]. Each entity at level 0 is responsible for a single LP and associated with the end-to-end monitor integrated in the S-BVT (a Subcarrier mod. RX of Fig. 1a); each entity at level 1 is responsible for LPs starting from a given ingress node; the OAM Handler is responsible for all the lightpaths.
- **Pre-programmed** (Fig. 1d): thanks to proper YANG models defined in[7], S-BVTs are instructed about the actions to perform in case of degradation, while the LP is still active. If a degradation occurs, S-BVT promptly reacts by self-reconfiguring the proper transmission parameters without asking and waiting for computations to OAM Handler/SDN controller. Finally, the OAM Handler is notified about recovery.

Performance evaluation

We assessed the three OAM schemes through simulations in terms of *control plane recovery delay*, which is defined as the time between the failure is detected and the recovery is triggered. A custom built event-driven C++ simulator has been adopted and an European backbone topology considered. The network operates with Poisson traffic. The holding time of each connection is exponentially distributed with average $1/\mu = 1$ hour, while the mean inter-arrival time $1/\lambda$ is varied in the range 4.5 –72 seconds. The traffic load offered to the network is therefore expressed as λ/μ and is varied in the range 50 – 800 Erlang.

Fig. 2 shows the recovery time vs. the offered network load with a processing time of each alarm fixed at 50ms. This value has been derived by the experiment detailed in[4]. The recovery time is reported in average and as the maximum value experienced during the simulation. Centralized experiences the highest recovery delay – both maximum and in average – since a single entity receives and processes all the alarms before triggering recovery. Thus, alarm packets experience a high queuing time before being processed. Hierarchical experiences a lower recovery time than Centralized, since each monitoring entity at level 1 processes only a subset of alarms, thus queuing delays are strongly reduced. Specifically, in the considered scenario, the level-1 monitoring entity groups LPs per ingress node, therefore only alarms related to LPs starting from the same node are actually queued. Pre-programmed experiences the lowest recovery time since S-BVT can promptly react to the failure or degradation without waiting for a response on how to react but exploiting pre-instructions. Recovery delay increases with traffic load since more LPs are affected, more alarms are generated, and queuing time consequently increases. Interestingly, the recovery time with Pre-programmed is almost constant with the offered load thus increasing the scalability of the network.

Fig. 3 shows the recovery time vs. the processing time of an alarm with a fixed offered network load of 360 Erlang ($1/\mu = 1$ hour, $1/\lambda = 10$ seconds). The behaviour of the three compared schemes is confirmed and Centralized obtains the highest recovery delay while Pre-programmed the lowest. The recovery time increases with the processing time since the processing time influences the queuing time. Again, Pre-programmed experienced constant performance with the processing time making the system efficient. Finally, note that the gap between the schemes increases with the processing time.

Conclusions

This paper presented control and management of sliceable transponders through NETCONF in a SDN enviroment, where YANG models configuration and state transponder parameters. Three OAM schemes are also presented considering scalability issues in the management of alarms. An high workload of a centralized controller to process many alarms (e.g., due to soft failure) may result in delaying data plane device reconfiguration upon failure or degradation. Such issue can be overcome with smarter approaches like a hierarchical-based OAM or by pre-programming resilience schemes into data plane devices.

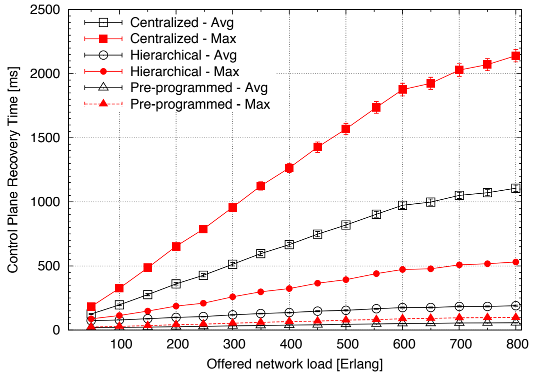


Fig. 2: Control plane recovery time vs. offered network load with a processing time of 50 ms.

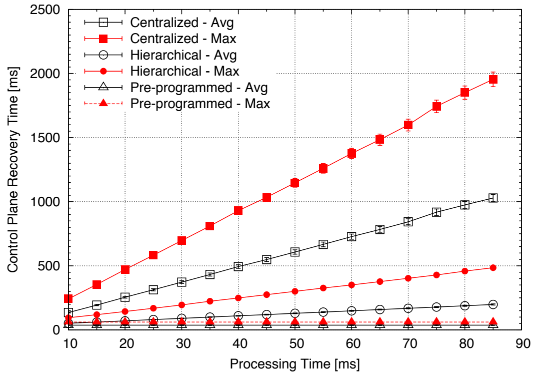


Fig. 3: Control plane recovery time vs. processing time at an offered network load of 360 Erlang.

Acknowledgements

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