TVR (Time-Variant Routing) Applicability

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What’s new in this version?

- Removed the “Use Case” section and **enriched Appendix A to cover every case** listed in RFC9657.
- Updated the “**Applicability of TVR YANG Model**” section.
- Added **CORECONF** as one of the optional management protocols.
- Enriched “**Operational Considerations**” section.
- Some editorial updates.

When TVR YANG Model is Applicable?

Applicability of Node YANG Module

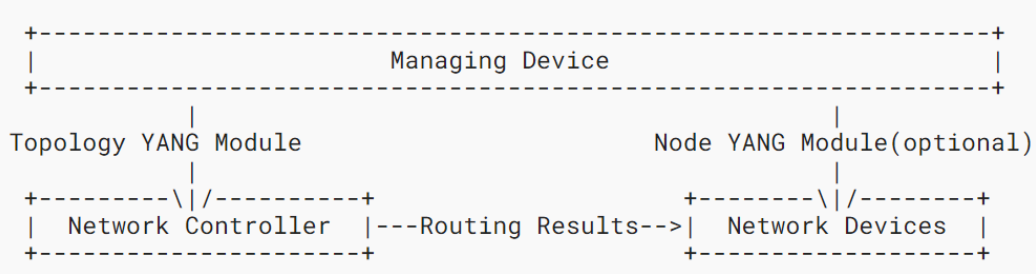
It depends on whether the topology changes are caused by the environment or centrally controlled.

- **Caused by the environment:** e.g. links may be powered off due to the movement, sunlight changes, or weather changes. **In this case, the Node YANG Module is not applicable.**

- **Caused by the centralized control**: In this case, the devices themselves do not know when to adjust the attributes. So the **Topology YANG Module is applicable to deliver the schedule of attribute changes.**

Applicability of Topology YANG Module

Schedule Generation	Schedule Execution	Applicable?
Distributed	Distributed	No
Centralized	Centralized(on the same devices)	No
Centralized	Centralized(on different devices)	Yes
Centralized	Distributed	Yes



Centralized schedule generation and execution but on different devices

How to encode TVR YANG Model?

- NETCONF
  - Provides a robust mechanism for managing complex network configurations;
  - Supports atomic transactions, which ensures schedules involving multiple resources are applied fully, preventing partial updates.
  - Supports the validation of configurations prior to commitment;
- RESTCONF
  - Provides a simpler, stateless method for interacting with network devices;
  - Provides a streamlined approach to network configuration and management by RESTful interface over HTTP;
- CORECONF
  - Provides a lightweight, stateless method for managing small network devices where saving bytes to transport a message is very important.
  - Uses CoAP methods to access structured data defined in YANG
  - Advantageous in networks with constrained devices and very limited transmission bandwidth, especially in IoT devices that already deployed CoAP.
- Summary
  - NETCONF would be the preferred protocol for **large-scale, critical scheduling operations requiring validation and rollback mechanisms**.
  - RESTCONF would be the preferred protocol for **smaller-scale or isolated scheduling tasks**.
  - CORECONF would be the preferred protocol for **resource constrained IoT networks where saving message bytes is a priority.**

Time Synchronization Mechanisms

- Hardware-based time synchronization:
  - **Features:** **Rely on dedicated hardware** to ensure clock synchronization, **have higher precision and stability**, but also **higher cost**.
  - **GNSS(Global Navigation Satellite System):** provides a precise time synchronization service based on the signals transmitted by the satellites. It is preferred for **large-scale, high dynamic** and open-air networks, especially networks with **unreliable links**. → **Nanoseconds**
  - **PTP(Precision Time Protocol):** a network protocol that complies with the IEEE 1588 standard. Based on the hardware timestamp, the precision of time synchronization is much higher than that of NTP. It is preferred for **small-scale** networks with **stable links** but have high-precision time synchronization requirements. → **Sub-microseconds**
- Software-based time synchronization:
  - **Features:** **Synchronize clocks through software packages running on systems**, **applicable to common hardware devices**, but have **lower precision**.
  - **NTP:** An application layer protocol in the TCP/IP protocol suite. It is used to synchronize clocks between clients and servers. It is preferred in **large-scale** networks with **reliable links** and **long-term changes**. → **Tens of milliseconds**
  - **SNTP:** A subset of NTP, which simplifies the complex NTP synchronization function. It is preferred for large- scale networks with reliable links, long-term changes, and **limited resources**. → **Seconds**

Operational Considerations

- **Schedule Dissemination**
  - The managed devices that **receives a schedule should have the ability** to execute the schedule.
  - Before distributing, the managing device need **to ensure that the time is synchronized** with that of the managed device.
  - The distributing of a schedule should **be earlier than the earliest start time of the schedule**, ensuring the managed device has enough time to execute this schedule.
- **Schedule Execution:**
  - **Node Schedule:** The schedule executor should undertake an action at specified time points as indicated in the schedule.
  - **Topology Schedule:** A link coming up or a node joining a topology, then the network **should not have any functional change until the change is proven to be fully operational**
  - **Topology Schedule:** A link or node is to be removed from the topology, then the network **should act before the anticipated change to route traffic** around the expected topological change.
- **Schedule Recovery:**
  - A node **lost its specific schedule data**: once the connection between the managed device and the managing device is established again, the managing device **should re-distribute all schedules** that start time is later than the current moment to the managed device.
- **Error Handling:**
  - If the **time parameters of a schedule conflict with each other**, then the schedule should be discarded.
  - If the **time parameters are conflicted between schedules**, then all conflicting schedules should be discarded.

Appendix A: Code Examples

- Code Examples for “Energy-harvesting Wireless Sensor Network”
- Code Examples for "Cellular Network"
- Code Examples for “Tidal Network”
- Code Examples for “Mobile Satellites”
- Code examples for “Predictable Moving Vessels”


```
{
    "ietf-tvr-node:node-schedule": {
        "node-id": "192.168.0.1",
        "node-power-schedule": {
            "power-default": true,
            "schedules": []
        },
        "interface-schedule": {
            "interfaces": [
                "name": "interface2",
                "default-available": false,
                "schedules": [
                    "schedule-id": 100,
                    "recurrence-first": {
                        "start-time-utc": "2026-01-01T08:00:00Z",
                        "duration": 54000
                    },
                    "utc-until": "2027-01-01T00:00:00Z",
                    "frequency": "ietf-schedule:daily",
                    "attr-value": {
                        "available": true
                    }
                ]
            ]
        }
    }
}
```


TVR Node YANG Schedule example for “Tidal Network”


```
{
    "ietf-tvr-topology:topology-schedule": {
        "nodes": [
            {
                "node-id": "192.168.0.1",
                "available": {
                    "default-node-available": true,
                    "schedules": []
                }
            },
            {
                "node-id": "192.168.0.2",
                "available": {
                    "default-node-available": true,
                    "schedules": []
                }
            },
            {
                "node-id": "192.168.0.3",
                "available": {
                    "default-node-available": true,
                    "schedules": []
                }
            },
            {
                "node-id": "192.168.0.4",
                "available": {
                    "default-node-available": true,
                    "schedules": []
                }
            }
        ],
        "links": [
            {
                "source-node": "192.168.0.1",
                "source-link-id": "link2",
                "available": {
                    "schedules": [
                        {
                            "schedule-id": 100,
                            "recurrence-first": {
                                "start-time-utc": "2026-01-01T08:00:00Z",
                                "duration": 54000
                            },
                            "utc-until": "2027-01-01T00:00:00Z",
                            "frequency": "ietf-schedule:daily",
```


TVR Topology YANG Schedule example for “Tidal Network”

Next Steps

- Welcome for contribution and comments.
- Ready for WG adoption?

- Repository: https://github.com/zhangli-abcd/TVR-Applicability