



# SDN at L0 with sysrepo

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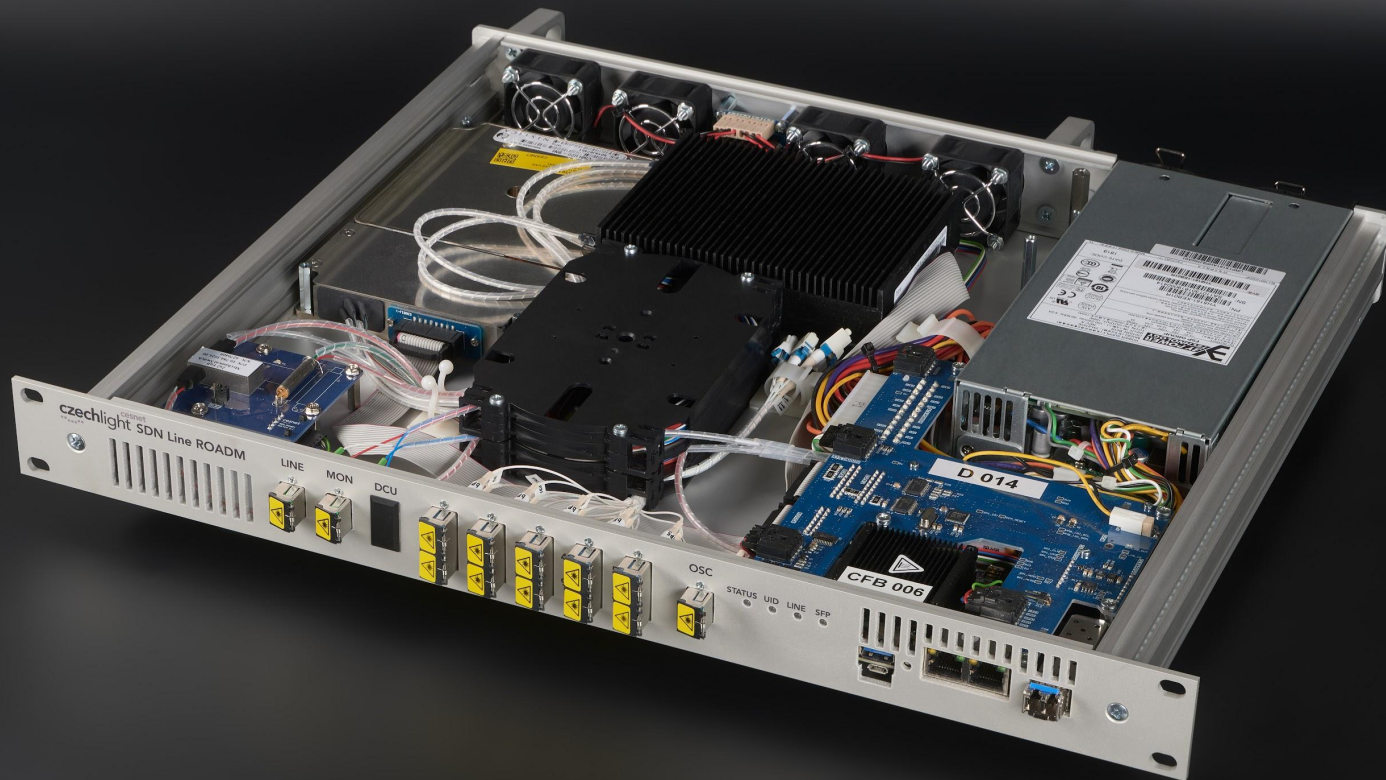


Modular Open  
Optical Line  
System

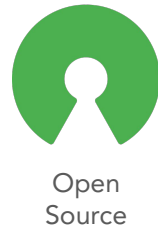
SDN at L0

Open Design

Flexgrid,  
Colorless,  
Directionless,  
Contentionless



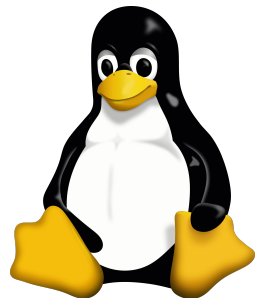
- Read-only Linux rootfs via **buildroot**
  - Stateless system
    - Except the YANG database (and some bits for early boot)
- Userland based on **systemd**
- A/B software slots via **rauc**
  - Integrated with HW watchdog
  - Atomic system updates



[ ● ◀ ] **systemd**

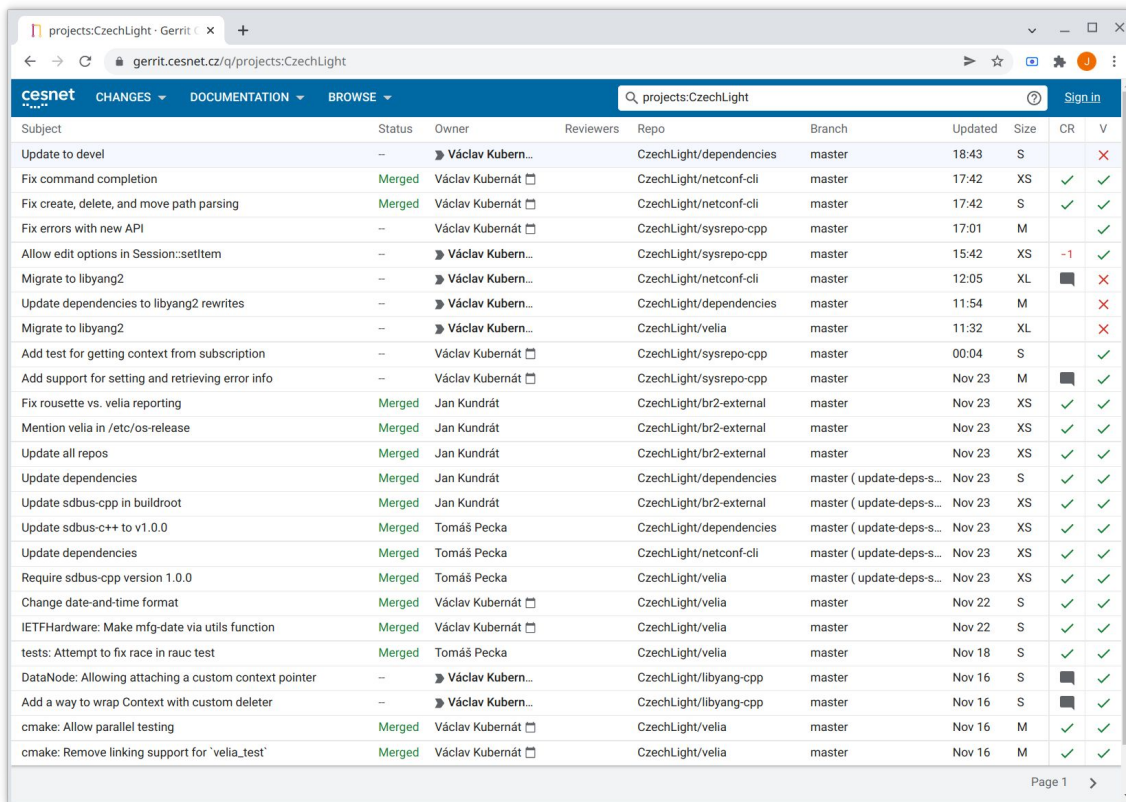


**Bootloader**



<https://gerrit.cesnet.cz/>

br2-external docs 



The screenshot shows the Gerrit web interface for the 'cesnet' project. The table lists various code changes, including updates to dependencies, command completion, and testing. The 'Status' column indicates whether a change is 'Merged' or 'In Progress'. The 'Owner' column shows the person responsible for the change. The 'Repo' column lists the repository name, and the 'Branch' column shows the branch name. The 'Updated' column shows the date and time of the last update. The 'Size' column shows the size of the change in lines of code. The 'CR' column shows the change number. The 'V' column shows the version number.

Subject	Status	Owner	Reviewers	Repo	Branch	Updated	Size	CR	V
Update to devel	--	Václav Kubernát		CzechLight/dependencies	master	18:43	S		✗
Fix command completion	Merged	Václav Kubernát		CzechLight/netconf-cli	master	17:42	XS	✓	✓
Fix create, delete, and move path parsing	Merged	Václav Kubernát		CzechLight/netconf-cli	master	17:42	S	✓	✓
Fix errors with new API	--	Václav Kubernát		CzechLight/sysrepo-cpp	master	17:01	M		✓
Allow edit options in Session::setItem	--	Václav Kubernát		CzechLight/sysrepo-cpp	master	15:42	XS	-1	✓
Migrate to libyang2	--	Václav Kubernát		CzechLight/netconf-cli	master	12:05	XL		✗
Update dependencies to libyang2 rewrites	--	Václav Kubernát		CzechLight/dependencies	master	11:54	M		✗
Migrate to libyang2	--	Václav Kubernát		CzechLight/velia	master	11:32	XL		✗
Add test for getting context from subscription	--	Václav Kubernát		CzechLight/sysrepo-cpp	master	00:04	S		✓
Add support for setting and retrieving error info	--	Václav Kubernát		CzechLight/sysrepo-cpp	master	Nov 23	M		✓
Fix rousette vs. velia reporting	Merged	Jan Kunderát		CzechLight/br2-external	master	Nov 23	XS	✓	✓
Mention velia in /etc/os-release	Merged	Jan Kunderát		CzechLight/br2-external	master	Nov 23	XS	✓	✓
Update all repos	Merged	Jan Kunderát		CzechLight/br2-external	master	Nov 23	XS	✓	✓
Update dependencies	Merged	Jan Kunderát		CzechLight/dependencies	master (update-deps-s...	Nov 23	S	✓	✓
Update sdbus-cpp in buildroot	Merged	Jan Kunderát		CzechLight/br2-external	master (update-deps-s...	Nov 23	XS	✓	✓
Update sdbus-c++ to v1.0.0	Merged	Tomáš Pecka		CzechLight/dependencies	master (update-deps-s...	Nov 23	XS	✓	✓
Update dependencies	Merged	Tomáš Pecka		CzechLight/netconf-cli	master (update-deps-s...	Nov 23	XS	✓	✓
Require sdbus-cpp version 1.0.0	Merged	Tomáš Pecka		CzechLight/velia	master (update-deps-s...	Nov 23	XS	✓	✓
Change date-and-time format	Merged	Václav Kubernát		CzechLight/velia	master	Nov 22	S	✓	✓
IETFHardware: Make mfg-date via utils function	Merged	Václav Kubernát		CzechLight/velia	master	Nov 22	S	✓	✓
tests: Attempt to fix race in rauc test	Merged	Tomáš Pecka		CzechLight/velia	master	Nov 18	S	✓	✓
DOMNode: Allowing attaching a custom context pointer	--	Václav Kubernát		CzechLight/libyang-cpp	master	Nov 16	S		✓
Add a way to wrap Context with custom deleter	--	Václav Kubernát		CzechLight/libyang-cpp	master	Nov 16	S		✓
cmake: Allow parallel testing	Merged	Václav Kubernát		CzechLight/velia	master	Nov 16	M	✓	✓
cmake: Remove linking support for 'velia_test'	Merged	Václav Kubernát		CzechLight/velia	master	Nov 16	M	✓	✓



# C++ bindings

## ■ Modern C++ idioms

- Value-based ownership
- Automatic memory management

```
auto root = ctx.parseData(..., libyang::DataFormat::JSON);
auto x = ctx.parseData(..., libyang::DataFormat::JSON);

root->findPath("/example:abc")->merge(x);

auto coll = x->childrenDfs();
x = std::find_if(coll.begin(), coll.end(), [] (const auto& node) {
    return node.asTerm().valueStr() == "666";
});

assert(root->nextSibling()->nextSibling()->path() == "/example-schema:bigTree");
```

## ■ Modern C++ idioms

- Lambda functions
- Nice exceptions

```
auto session = sysrepo::Connection{}.sessionStart();
auto sub = session.onModuleChange("module", [](auto session, auto, auto, auto, auto, auto) {
    for (const auto& change : session.getChanges()) {
        std::cout << change.node.path() << ": " << *change.previousValue.or_else("[nothing]")
            << " -> " << change.node.asTerm().valueStr() << "\n";
    }
    return sysrepo::ErrorCode::Ok;
});

session.setItem("/module:myCont/myLeaf", "some-value");
session.applyChanges();

if (auto data = session.getData("/module:myCont/myLeaf")) {
    std::cout << data.findPath("/module:myCont/myLeaf")->asTerm().valueStr() << "\n";
}
```

## ■ Idiomatic Python interface

- Built on top of libyang-cpp
- Binary wheels available via PyPI (Linux x86\_64, Mac OS X, Windows)

```
for x in data.siblings():
    print(f'a sibling: {x.path}')
    for xx in x.children_dfs():
        print(f' {"term " if xx.is_term else "child"}: {xx.path}')
        if xx.is_term:
            print(f' {xx.as_term()} {" (default)" if xx.as_term().is_default_value else ""}')
```

*# Multi-level XPath*

```
data["interface[name='lo']/ietf-ip:ipv6/address[ip='::1']/prefix-length"].as_term().value == 128
```

*# Level-by-level*

```
data["interface[name='lo']"] ["ietf-ip:ipv6"] ["address[ip='::1']"] ["prefix-length"].as_term().value
```

*# Taking a shortcut for one-element lists*

```
data["interface[name='lo']"] ["ietf-ip:ipv6"] ["address"] ["prefix-length"].as_term().value == 128
```





# Application Software

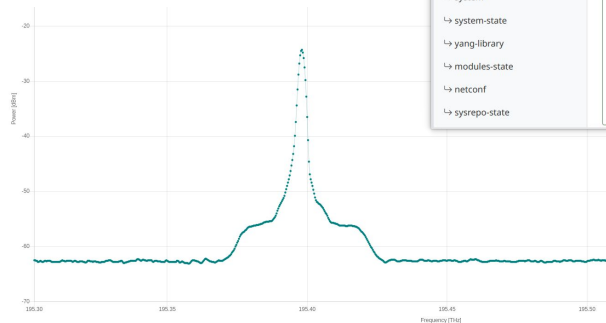
- Console CLI
  - NETCONF
  - Standalone YANG
  - Direct sysrepo
  - Suitable as a “login shell”
- Fancy Tab completion
  - Context-sensitive
  - Built on-the-fly from YANG models

```
ietf-truststore:truststore/
sysrepo-plugin:sysrepo-plugin/
/> set czechlight-
czechlight-roads-device:channel-plan/      czechlight-roads-device:media-channels
czechlight-roads-device:leaf-ports         czechlight-roads-device:spectrum-scan/
czechlight-roads-device:line/              czechlight-system:authentication/
/> set czechlight-
czechlight-roads-device:channel-plan/      czechlight-roads-device:media-channels
czechlight-roads-device:leaf-ports         czechlight-roads-device:spectrum-scan/
czechlight-roads-device:line/              czechlight-system:authentication/
/> set czechlight-roads-device:media-channels[channel='C-band']/
add/      channel      description      drop/
/> set czechlight-roads-device:media-channels[channel='C-band']/add/
attenuation      port      power
/> set czechlight-roads-device:media-channels[channel='C-band']/add/port E
E1 E2 E3 E4 E5 E6 E7 E8 E9
/> set czechlight-roads-device:media-channels[channel='C-band']/add/port E5
/> commit
Error: Mandatory choice "mode" data do not exist. (Data location "/czechlight-roads-device:
media-channels[channel='C-band']/add".)
Error: User callback failed.

/> commit
```

## ■ RESTCONF server

- Almost RESTCONF server
  - Basic GET – full content, subtrees, leafs,...
  - Basic PUT – subtrees, leafs
  - Telemetry (WIP)
- Patches welcome



cesnet		line-qr79
↳ nbr-list	eth0	iana-if-type: ethernetCsmacd
↳ channel-plan	type	up
↳ media-channels	state	00:11:17:01:00:2e
↳ aggregate-power	physical address	IN (oct/err/ds): 488342/0/0   OUT (oct/err/ds): 53565126/0/0
↳ line	statistics	
↳ firmware	IPv4	
↳ authentication	IPv6	
↳ leds	eth1	iana-if-type: ethernetCsmacd
↳ hardware	type	down
↳ interfaces	state	00:11:17:01:00:2f
↳ keystore	physical address	IN (oct/err/ds): 0/0/0   OUT (oct/err/ds): 0/0/0
↳ nacm	statistics	
↳ netconf-state	IPv4	
↳ netconf-server	IPv6	
↳ routing	OSC	iana-if-type: ethernetCsmacd
↳ streams	type	down
↳ system	state	00:11:17:01:00:30
↳ system-state	physical address	IN (oct/err/ds): 0/0/0   OUT (oct/err/ds): 0/0/0
↳ yang-library	statistics	
↳ modules-state	IPv4	
↳ netconf	IPv6	
↳ sysrepo-state	br0	iana-if-type: bridge
	type	up
	state	00:11:17:01:00:2e
	physical address	IN (oct/err/ds): 399873/0/0   OUT (oct/err/ds): 53564019/0/0
	statistics	10.0.254.79 prefix: 24
	IPv4	↳ neigh: 10.0.0.1 link-layer-addr: cc:2d:e0:52:30:9c
		↳ neigh: 10.0.254.1 link-layer-addr: cc:2d:e0:52:30:9c
		↳ neigh: 10.0.254.98 link-layer-addr: 4a:2a:8d:2f:35:00
	IPv6	fe80::211:17ff:fe01:2e prefix: 64

## ■ System management

- Network via `ietf-interfaces`, `ietf-routing` and `systemd-networkd`
  - Config generator
  - Runtime statistics through `libnl`
  - LLDP, DHCP client, bridging
- Firewall via `ietf-access-control-list` and `nftables`
- User accounts, passwords, SSH keys
- RAUC firmware updates

## ■ Health tracking

- Sensors from Linux' `sysfs` into `ietf-hardware`
- Failed `systemd` units
- `ietf-alarms` integration
- LEDs



## ■ ietf-alarms from RFC 8632

- Common infrastructure for sysrepo apps
- Inventory, shelving & filtering
- In future, history

```
module: sysrepo-ietf-alarms
```

```
rpcs:
```

```
  +---x create-or-update-alarm
```

```
    +---w input
```

```
      +---w resource
```

```
      al:resource
```

```
      +---w alarm-type-id
```

```
      al:alarm-type-id
```

```
      +---w alarm-type-qualifier?
```

```
      al:alarm-type-qualifier
```

```
      +---w severity
```

```
      al:severity-with-clear
```

```
      +---w alarm-text
```

```
      al:alarm-text
```



Patches Welcome!



## ■ Product web

- <https://czechlight.cesnet.cz/en/open-line-system/sdn-roadm/>

## ■ Journal Publications

- YANG/NETCONF ROADM: Evolving Open DWDM Toward SDN Applications (JLT 2018).
- Opening up ROADMs: Let Us Build a Disaggregated Open Optical Line System (JLT 2019).
- Opening up ROADMs: a filterless add/drop module for coherent-detection signals (JOCN 2020).
- Opening up ROADMs: streaming telemetry [Invited] (JOCN 2021).

## ■ Conference Demos

- Chatty ROADMs: Streaming Telemetry with Open Source SW and Open Hardware (ECOC 2021)
- GNPY & YANG: Open APIs for End-to-End Service Provisioning in Optical Networks (OFC 2021)
- Physical-layer awareness: GNPY and ONOS for end-to-end circuits in disagg. networks (OFC 2020)
- Opening up ROADMs: Let's Build a Disaggregated Open Optical Line System (ONF Connect 2019)
- ...





# Q&A

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