Automating ns-3 Experimentation in Multi-Host Scenarios

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ns-3 features for advanced simulations

- ns-3 is a modular discrete-event network simulator that provides
  - application and protocol emulation with DCE,
  - special devices (e.g., FD and Tap NetDevice),
  - real-time scheduler,
  - interactive mode.

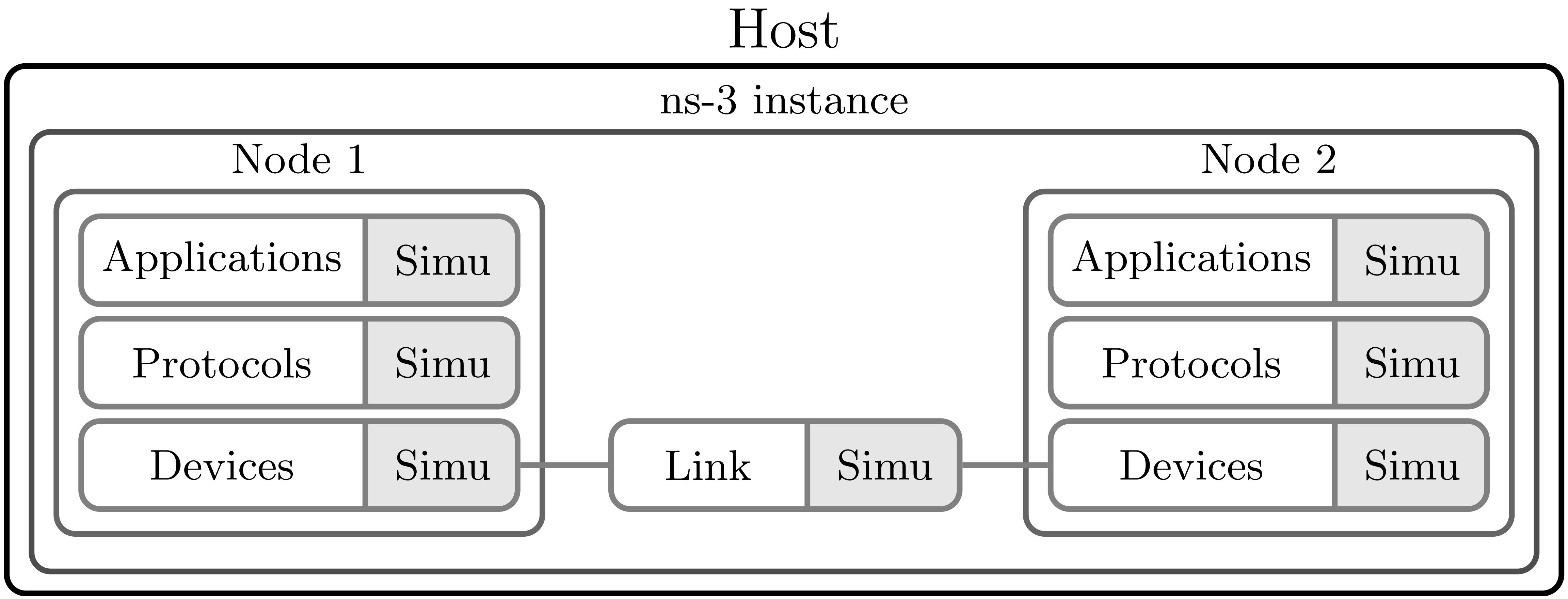
ns-3 features for advanced simulations

- ns-3 is a modular discrete-event network simulator that provides

Why is that interesting?

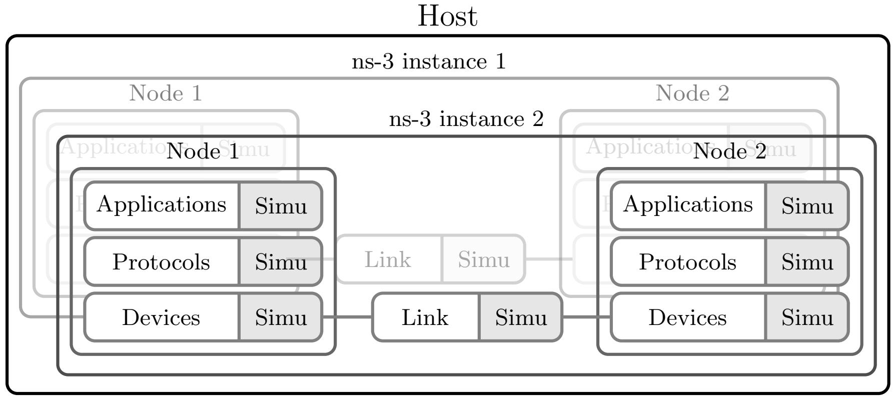
  - real-time scheduler,
  - interactive mode.

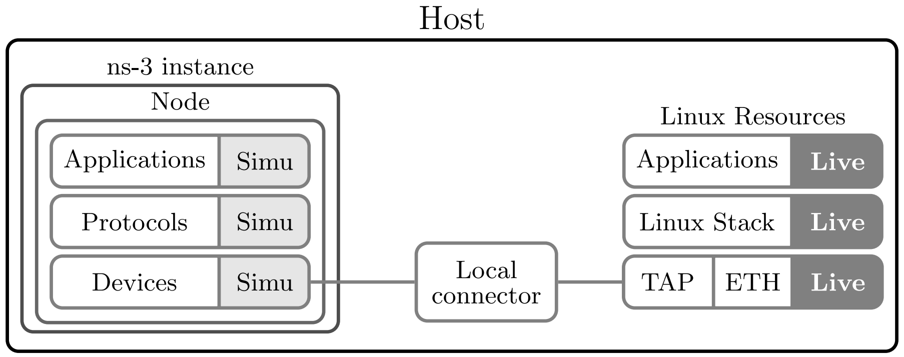
ns-3 is modular

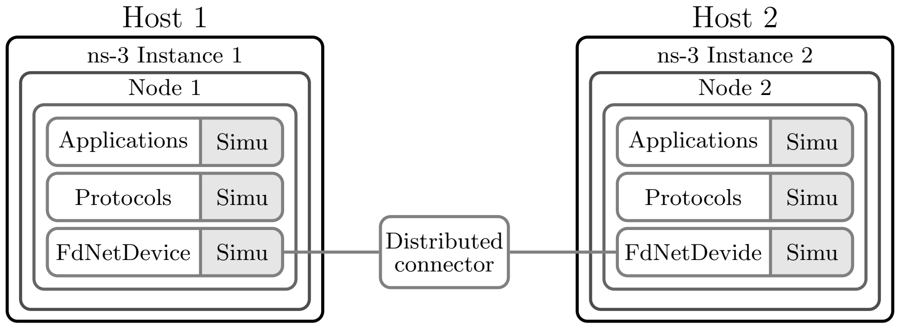


ns-3 is more than a simulator

- Parallelisation
  - run independent simulations.
- Hybrid emulation
  - connect simulations with a real system.
- Distributed simulations
  - span the simulation over multiple hosts.







ns-3 is more than a simulator

- Parallelisation
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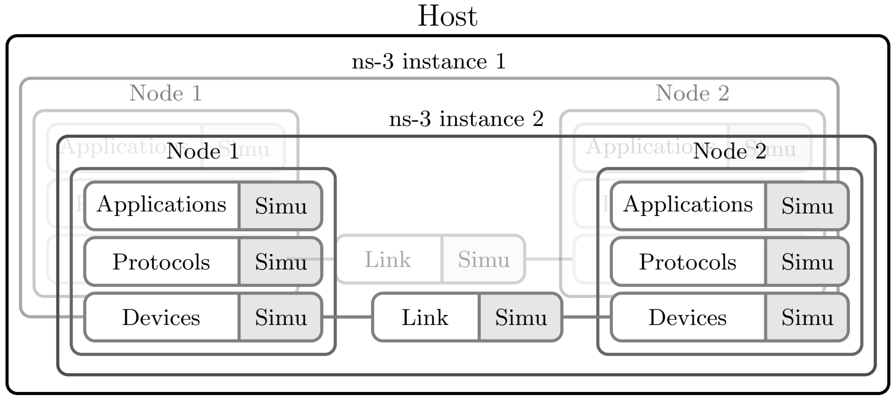
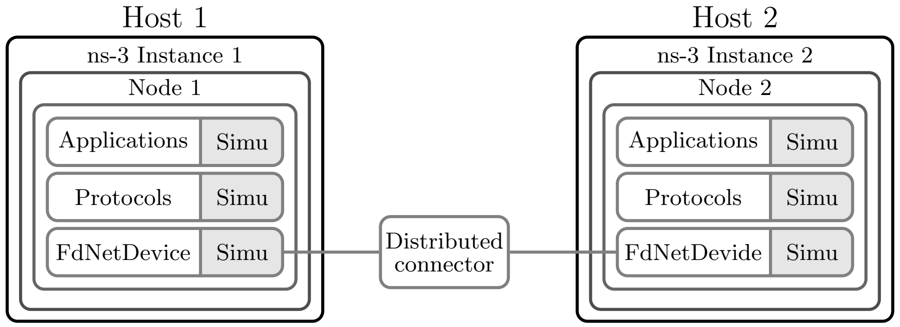


This is fastidious
(e.g., configuration, synchronisation)

- Distributed simulations
  - span the simulation over multiple hosts.



NEPI to make it easy

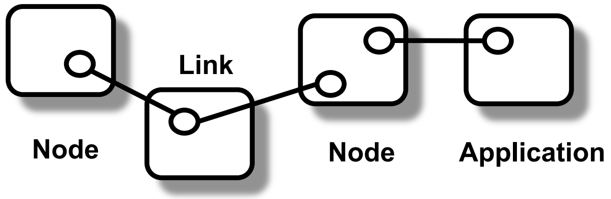
- NEPI, Network Experiment Programming Interface, is a framework to manage network experiments
  - that abstracts components behind a common interface: the resource
  - to automate experimentation steps.
- Runs locally, no need to modify the experiment facility
  - e.g., ns-3, PlanetLab.

Everything is a resource

- The user interacts with the Experiment Controller (EC), which controls the resources.
- Every resource implements the same interface
    - e.g., `deploy`, `start`, `stop`.

Experiment representation

- An experiment is a graph of interconnected resources.



- Each resource has 3 set of properties:
  - attributes (e.g., configuration),
  - traces (e.g., stderr, stdout),
  - states (i.e., `STARTED`, `STOPPED`, `FAILED`).

Ping example

```
from nepi.execution.ec import ExperimentController
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ec = ExperimentController(exp_id="ping")
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node = ec.register_resource("linux::Node")

ec.set(node, "hostname", "my-hostname")

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app = ec.register_resource("linux::Application")

ec.set(app, "command", "ping -c3 192.168.0.1")

ec.register_connection(node, app)

ec.deploy()

ec.wait_finished(app)
```

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ec.register_connection(node, app)

ec.deploy()

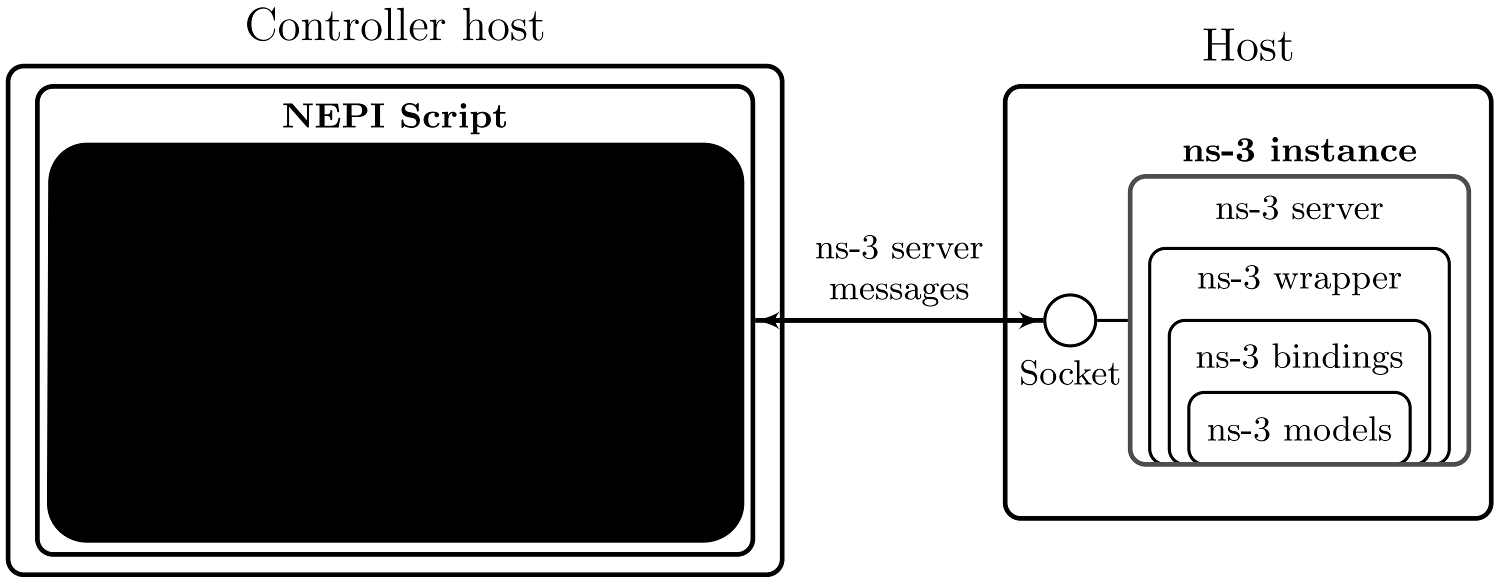
ec.wait_finished(app)

print ec.trace(app, "stdout")

ec.shutdown()
```

NEPI for ns-3

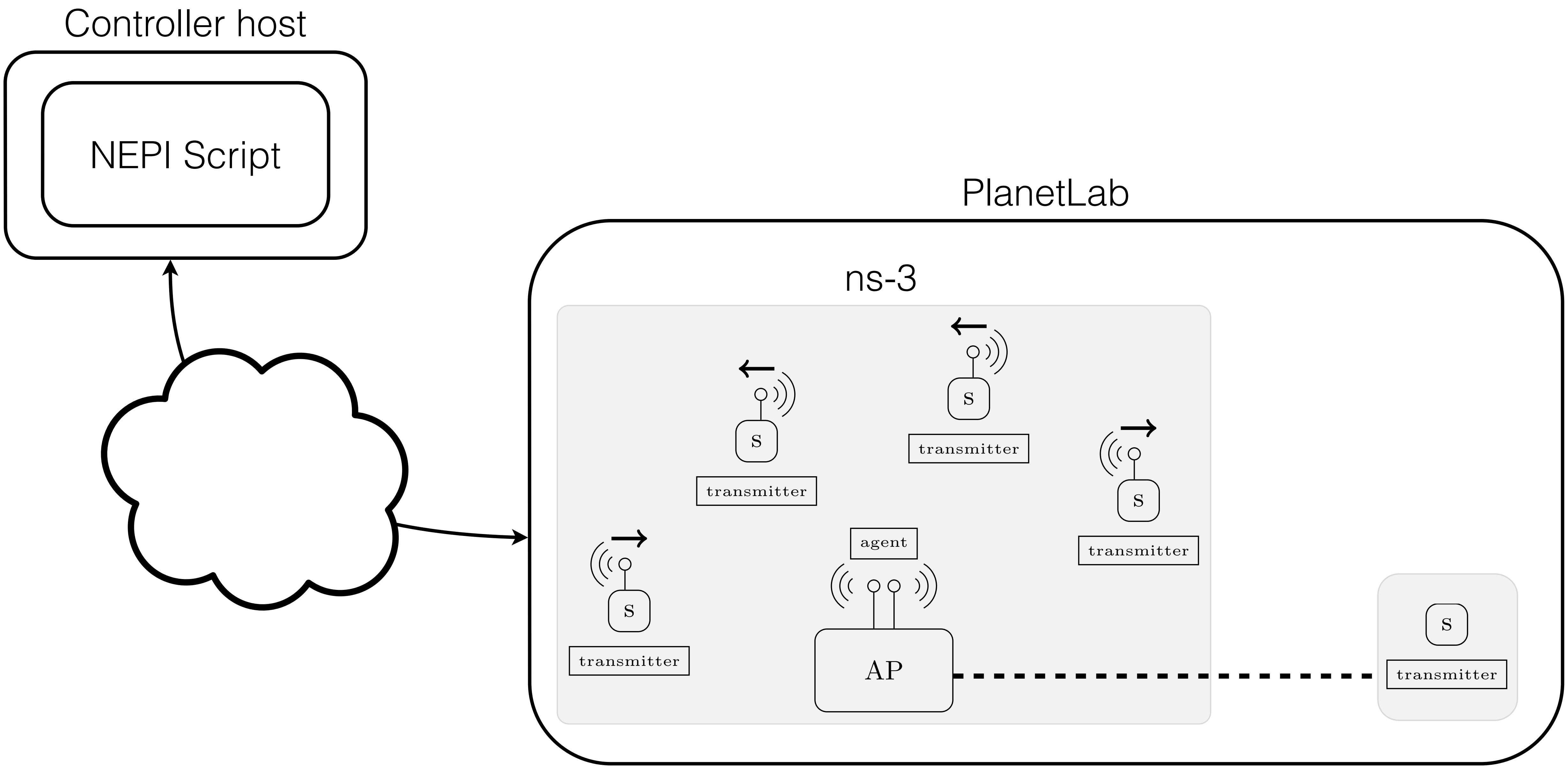
- NEPI controls (remote) ns-3 simulations
  - via ns-3 Python bindings
  - and a message passing protocol.



Hands-on*

* with simplified code, see the paper for the exact code

A mobility use case with simulated and real nodes



To do list

- Deploy ns-3 on a PlanetLab host
  - Model the simulated network in ns-3
  - Run a real transmitter application
  - Interconnect the ns-3 instance with the real transmitter application
  - Run the experiment

Deploy ns-3 on PlanetLab

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```
ec = ExperimentController(exp_id="hybrid")
```

Deploy ns-3 on PlanetLab

```
ec = ExperimentController(exp_id="hybrid")

host = ec.register_resource("planetlab::Node")

ec.set(host, "hostname", hostname)

ec.set(host, "username", username)

ec.set(host, "identity", ssh_key)
```

Deploy ns-3 on PlanetLab

```
ec = ExperimentController(exp_id="hybrid")

host = ec.register_resource("planetlab::Node")

ec.set(host, "hostname", hostname)

ec.set(host, "username", username)

ec.set(host, "identity", ssh_key)

simu = ec.register_resource("linux::ns3::Simulation")
```

Deploy ns-3 on PlanetLab

```
ec = ExperimentController(exp_id="hybrid")

host = ec.register_resource("planetlab::Node")

ec.set(host, "hostname", hostname)

ec.set(host, "username", username)

ec.set(host, "identity", ssh_key)

simu = ec.register_resource("linux::ns3::Simulation")

ec.register_connection(simu, host)
```

Model the simulated network in ns-3 - the topology

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```
channel = ec.register_resource("ns3::YansWifiChannel")
```

Model the simulated network in ns-3 - the topology

```
channel = ec.register_resource("ns3::YansWifiChannel")

ap = add_ns3_node(ec, simu, agent_ip, prefixlen,
                  channel, ap_mode=True)
```

Model the simulated network in ns-3 - the topology

```
channel = ec.register_resource("ns3::YansWifiChannel")

ap = add_ns3_node(ec, simu, agent_ip, prefixlen,
                  channel, ap_mode=True)

agent = add_dce_agent(ec, ap)
```

Model the simulated network in ns-3 - the topology

```
channel = ec.register_resource("ns3::YansWifiChannel")

ap = add_ns3_node(ec, simu, agent_ip, prefixlen,
                  channel, ap_mode=True)

agent = add_dce_agent(ec, ap)

for ip in ips:

  sensor = add_ns3_node(ec, simu, ip, prefixlen,
                        channel, ap_mode=False)

  transmitter = add_dce_transmitter(ec, sensor, agent_ip)

  add_ns3_route(ec, sensor, network="0.0.0.0/0", nexthop=agent_ip)
```

Model the simulated network in ns-3 - the nodes

```
def add_ns3_node(ec, simu, ip, prefixlen, channel, ap_mode=False):
```

Model the simulated network in ns-3 - the nodes

```
def add_ns3_node(ec, simu, ip, prefixlen, channel, ap_mode=False):

  ns3_node = ec.register_resource("ns3::Node")

  ec.set(ns3_node, "enableStack", True)
```

Model the simulated network in ns-3 - the nodes

```
def add_ns3_node(ec, simu, ip, prefixlen, channel, ap_mode=False):

  ns3_node = ec.register_resource("ns3::Node")

  ec.set(ns3_node, "enableStack", True)

  ec.register_connection(ns3_node, simu)
```

Model the simulated network in ns-3 - the nodes

```
def add_ns3_node(ec, simu, ip, prefixlen, channel, ap_mode=False):

  ns3_node = ec.register_resource("ns3::Node")

  ec.set(ns3_node, "enableStack", True)

  ec.register_connection(ns3_node, simu)

  dev, phy = add_ns3_wifi_device(ec, ns3_node, ip, prefixlen, ap_mode)

  ec.register_connection(channel, phy)
```

Model the simulated network in ns-3 - the nodes

```
def add_ns3_node(ec, simu, ip, prefixlen, channel, ap_mode=False):
  ns3_node = ec.register_resource("ns3::Node")
  ec.set(ns3_node, "enableStack", True)
  ec.register_connection(ns3_node, simu)
  dev, phy = add_ns3_wifi_device(ec, ns3_node, ip, prefixlen, ap_mode)
  ec.register_connection(channel, phy)
  if not ap_mode:
    add_ns3_random_mobility(ec, ns3_node)
  return ns3_node
```

Model the simulated network in ns-3 - the applications

```
def add_dce_transmitter(ec, ns3_node, target):
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Model the simulated network in ns-3 - the applications

```
def add_dce_transmitter(ec, ns3_node, target):

  transmitter = ec.register_resource("linux::ns3::dce::Application")
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Model the simulated network in ns-3 - the applications

```
def add_dce_transmitter(ec, ns3_node, target):

  transmitter = ec.register_resource("linux::ns3::dce::Application")

  ec.set(transmitter, "sources", "code/transmitter.c")

  ec.set(transmitter, "build", "gcc -fPIC -pie
           -rdynamic ${SRC}/transmitter.c -o ${BIN_DCE}/transmitter")

  ec.set(transmitter, "binary", "transmitter")

  ec.set(transmitter, "arguments", target)
```

Model the simulated network in ns-3 - the applications

```
def add_dce_transmitter(ec, ns3_node, target):

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           -rdynamic ${SRC}/transmitter.c -o ${BIN_DCE}/transmitter")

  ec.set(transmitter, "binary", "transmitter")

  ec.set(transmitter, "arguments", target)

  ec.register_connection(transmitter, ns3_node)

  return transmitter
```

Interconnect the ns-3 instance with the real transmitter application

- Attach a File Descriptor NetDevice to the ns-3 node constituting the access point (ns3::FdNetDevice).

- Create a TAP device on the PlanetLab host (planetlab::Tap).

- Connect the “real” TAP to the File Descriptor NetDevice (planetlab::ns3::TunTapFdLink).

- Add routes

    - to the simulated network via the access point (planetlab::Vroute),

    - to the real network via the TAP (ns3::Route).

Run the experiment

- ec.deploy()

Conclusion

- ns-3 provides all the building blocks to perform
  - distributed simulations
  - hybrid experiments
- but is fastidious to use as-is.
- NEPI hides the complexity of hybridation and distribution to automate ns-3 experiments.

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