OMNeT++ Goes Python

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Introduction

- After finishing OMNeT++ 6.0...

- We started playing around with Python because we saw huge potentials there

  - enthused by the Python-powered Analysis Tool
  - during INET development and maintenance, a Python REPL with a home-grown lib has grown to be an indispensable tool
  - discovered the **cppyy** C++ FFI Python package

(Snapshot from the office)

Areas where Python can be useful

- Setting up models (e.g. topology building)
- Extending the capabilities of NED expressions
- Implementing simulation-specific ad-hoc components (e.g. scenario managers, custom traffic generators, etc.)
- Simulation control (e.g. custom stop conditions)
- Managing and running simulations and simulation campaigns (workflow automation)
- Result analysis (inside and outside of the IDE)

- Disadvantages of Python in OMNeT++
  - speed (or lack thereof)
    - you want to keep Python code out of the “hot” parts of the model
  - the word “module” has become ambiguous
    - do you mean “importable Python file”, or “OMNeT++ simulation component”? ;-)

Upcoming Python-related tools

- Python in NED expressions
  - `pyeval()` and `pycode()` NED functions
- Modules implemented in Python
  - `@pythonClass` NED property
  - modules can be written from scratch, or subclassed from existing (e.g. INET) modules
- Simulation library as a Python package
  - `from omnetpp.runtime import *`
  - based on cppyy
- Python package for processing simulation results
  - `from omnetpp.scave import results, ...`
- Python package for managing and running simulations
  - `from omnetpp.simulation import *`

The pyeval(), pycode() NED functions

- **pyeval**(<expr>,...) - evaluates a Python expression string
  - `pyeval("2*3")`
  - `pyeval("x: 2*x", 3) --> 6`

- **pycode(**<block>,...**)** - evaluates a Python statement block
  - block must end in a "`return`" statement (like a function body)
  - `pycode("import math; return math.factorial(15)")`
  - `pycode("a,b: import math\nif a<0 or b<0: return math.nan\nreturn math.gcd(a,b)", 70, 62)`

More details about pyeval()/pycode(), @pythonClass and cppyy in Attila Török's Summit presentation: *Using Python within Simulations*

The @pythonClass NED property

- Denotes that module is implemented by a Python class

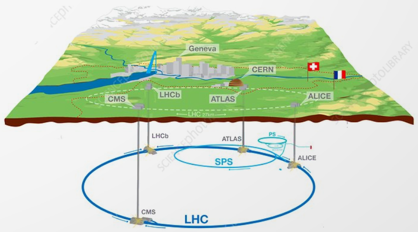
```
// sink.ned
simple Sink {
    parameters:
        @pythonClass;
        ...
}

# sink.py
from omnetpp.runtime import *

class Sink(omnetpp.cSimpleModule):
    def handleMessage(self, msg):
        ...
```

The cppyy package

- Dynamic runtime Python bindings for C++
  - allows cross-inheritance and callbacks, template instantiation and more
  - simple example:

```
import cppyy
cppyy.include("iostream")
cppyy.cppdef("""class A { public: void sayHello() { std::cout << "Hello" << std::endl; } };""")
A = cppyy.gbl.A
a = A()
a.sayHello()   # prints “Hello”
```

- Foundations:
  - Cling, the interactive C++ interpreter from CERN
  - Cling itself builds on Clang and LLVM
  - (at least this is what they want you to believe, but actually it relies on magic)



The omnetpp.runtime package

- Based on **cppyy**, it exposes the simulation library as a Python package
  - both simulation kernel and the “envir” infrastructure
  - its essence:

```
import cppyy
cppyy.include("omnetpp.h")
```

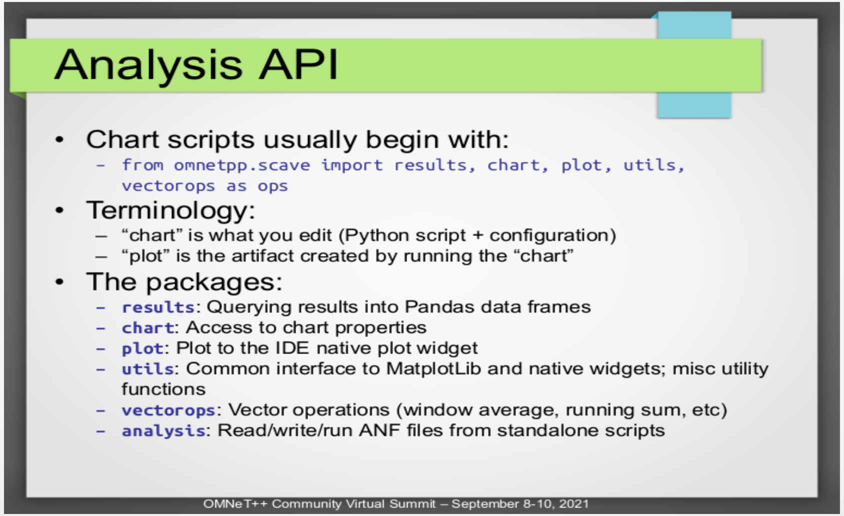
- OMNeT++ is undergoing extensive refactoring:
  - Reusability of “envir” part improved
  - Python readiness
  - Multi-thread support
    - Allow multiple threads to be used for simulation (but simulations are still *single-threaded!*)

      ```
      ./aloha -u Cmdenv --cmdenv-num-threads=8 ...
      ```

    - Global variables became `thread_local` or simulation-scope (`cSimulation::getSharedVariable<T>(name)` - new)

The omnetpp.scave package

- Part of OMNeT++ 6.0



Slide from last year's Summit

The omnetpp.simulation package

- Library and toolset for managing and running simulations and campaigns in various ways
  - in-process / local / distributed (e.g. ssh cluster using Dask)
  - for results, for regression testing (e.g. fingerprints), etc.
- Grown from the needs of INET development and maintenance
  - “run all simulations, utilizing all computing resources I have access to”
  - “refresh list of simulations to be fingerprint-tested”
  - “re-run failing fingerprint tests”
  - “re-run simulations that contain WiFi” (after WiFi model change)
  - “compare results to those with INET version X”
- Human time is expensive:
  - automate/assist as much as possible (high-level tools, REPL, etc)
  - store instead of recompute (fingerprints, simulation results, etc)
  - utilize available computing resources (multi-core, ssh cluster, etc)

DEMO

Recap of the Demo

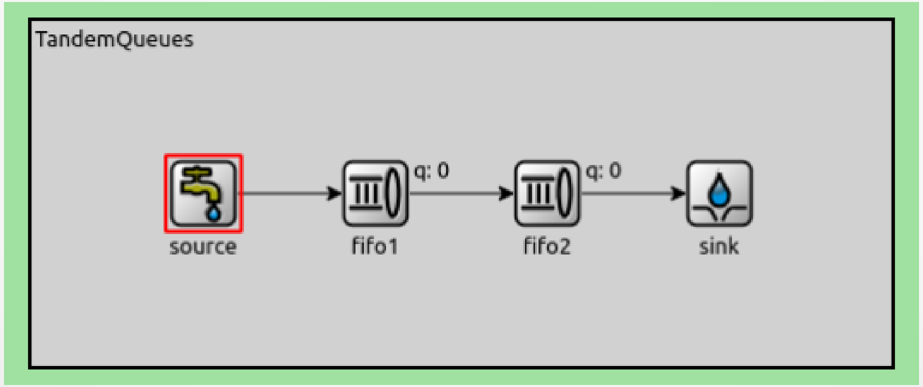
Python added to several OMNeT++ sample simulations:

- pyfifo: pure Python simple modules
- routing: various examples for making use of Python
- aloha: examples for running simulations from Python

To try, use the OMNeT++ version at the following URL:
https://drive.google.com/file/d/1jDD-vtzi9YVzShrw2fP6q1SUU5VMVsDM/view?usp=share_link

samples/pyfifo

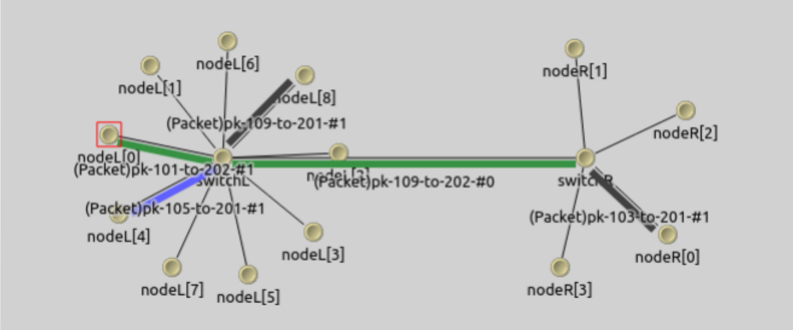
- A fairly verbatim re-implementation of the **fifo** example
- With all modules written in Python



samples/routing

Configurations in omnetpp.ini:

- `[FromCsv]`: Setting up a network specified in CSV, using Python
- `[RandomTree]`: Setting up a network generated with NetworkX Python package
- `[DumbbellFaultyLink]`: Shows a scenario manager written in Python
- `[AppExt]`: Extending a C++ simple module from Python
- `[App2]`: Parameter values produced using pyeval()/pycode()



samples/aloha

Python scripts:

- `example1.py`: instantiating a simulation

```
simulation = omnetpp.cSimulation(...)
```

- `example2.py`: all simulations in an omnetpp.ini parameter study

```
ini.getNumRunsInConfig("PureAlohaExperiment")
```

- `example3.py`: manually organizing a parameter study

```
for numHosts in [10,15,20]:
    for iaMean in [1,2,3,4,5,7,9]:
        ...
```

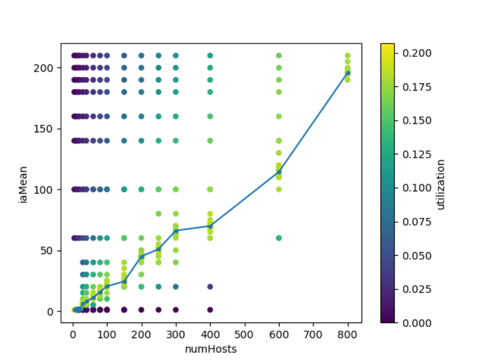
- `example4.py`: utilizing multiple CPU cores

```
with multiprocessing.Pool() as p:
    p.map(alohaJob, taskList)
```

- `example5.py`: simulation-based optimization

```
scipy.optimize.minimize(...)
```

- `example5a.py`: preserve and also plot all simulations



Questions?