Data Distribution Service for Python Applications

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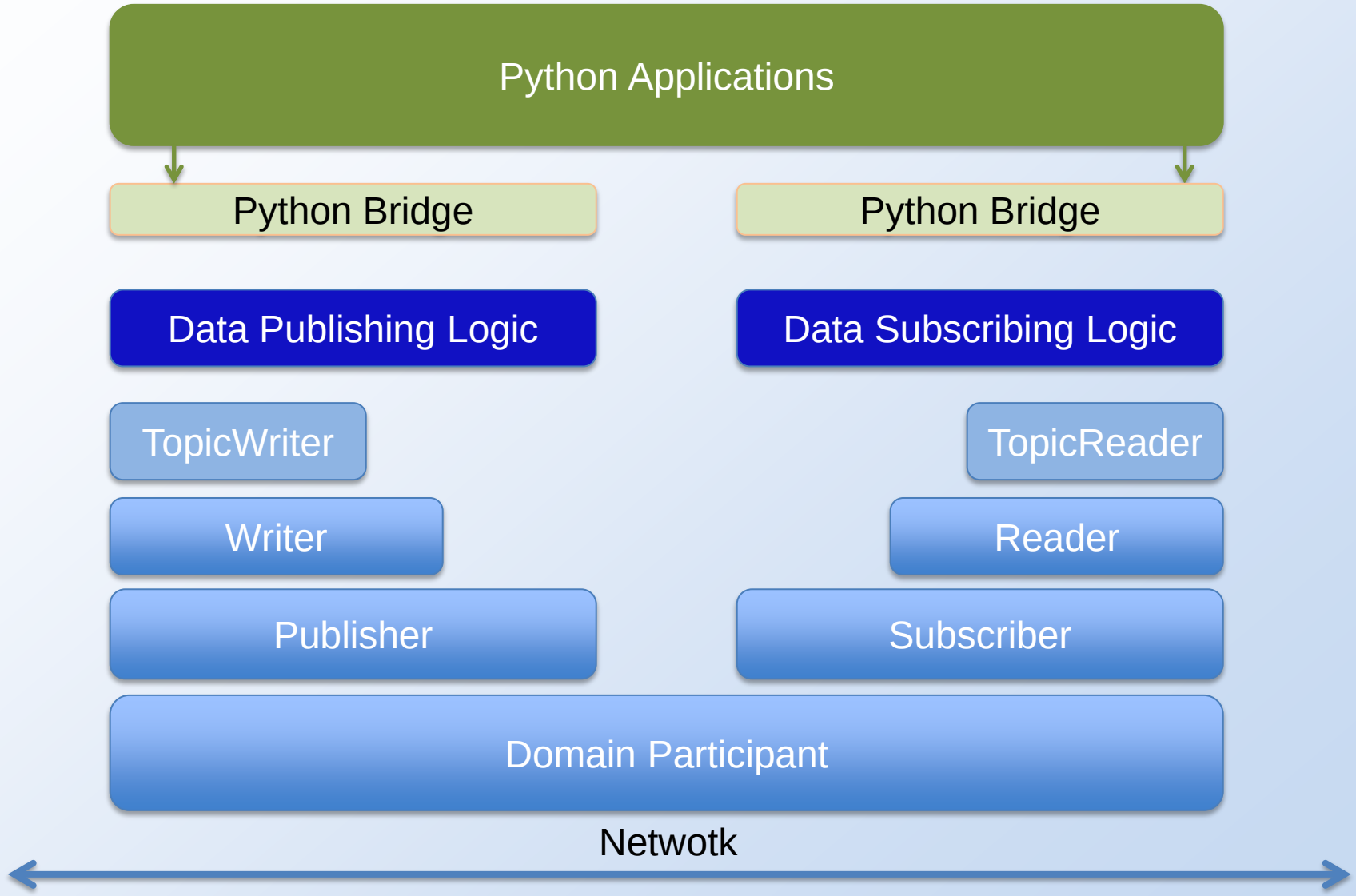
Introduction and Goal

- Why Python:
  - Python is a popular language due to its robust dynamic scripting language features and runtime supports
    - Rapid prototyping
    - Web scripting, XML processing,
    - GUI/database applications
    - Steering scientific applications
  - Many complex applications are based on Python with high-performance cores implemented using other technologies
- Currently, no standardized DDS Python mapping available and for developers to use DDS in their Python applications
- Hence the project goal is to
  - Implement a Python bridge for DDS to allow Python applications to participate in DDS data exchanges
  - Allow Python developers to interact with DDS data spaces directly
  - Eliminate the need to generate Python wrappers for topic-specificC/C++ mapping codes

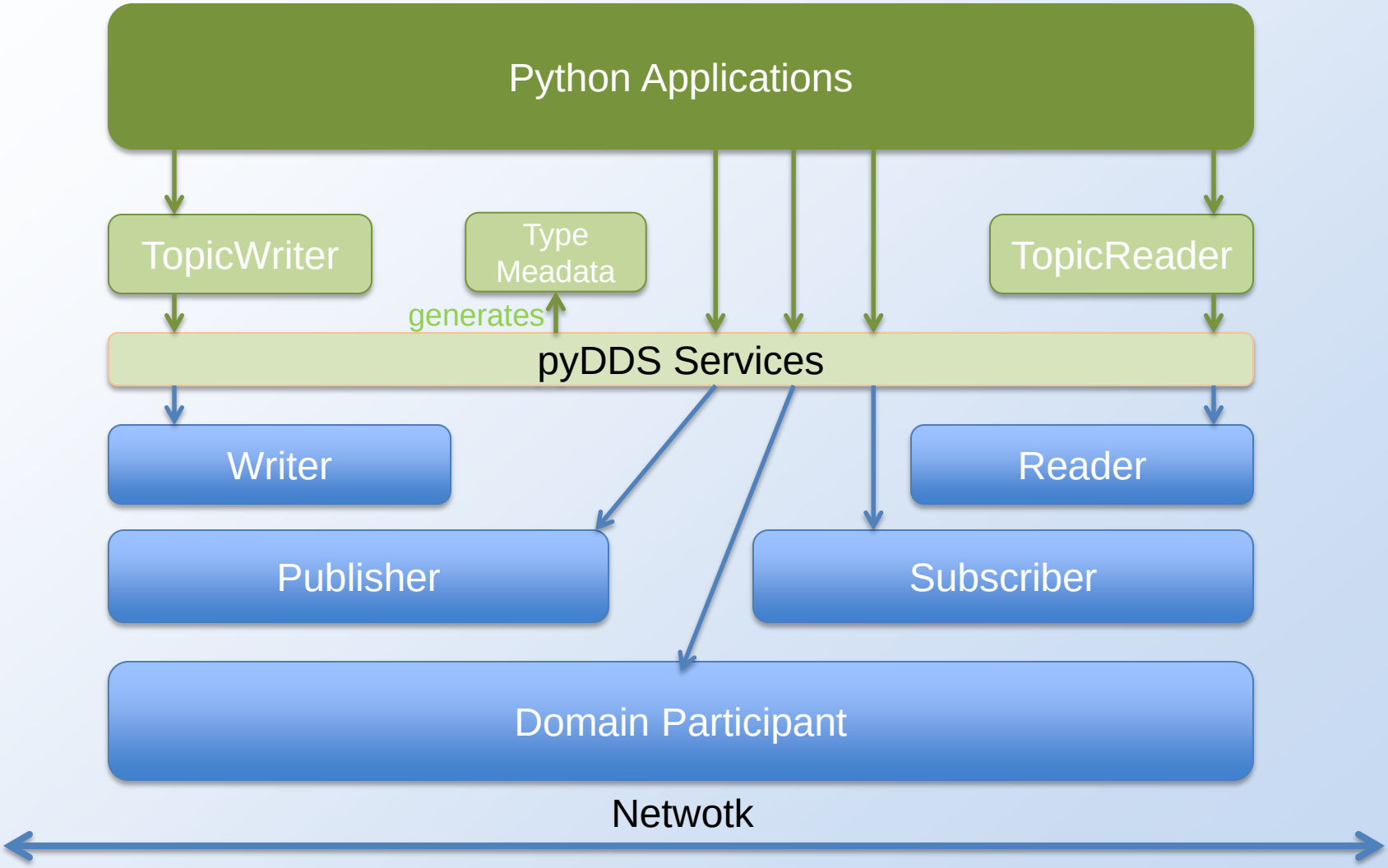
Typical Approach Puts the Bridge Above the Topic/Application level



Typical Approach Implies Regeneration of Glue for Each New Topic

- *Use vender provided tools such as "*idlpp*", to generate the* C/C++ mappings from type definitions
- Use some wrapper tools such as Boost.Python or SWIG, to wrap C/C++ code into bridges
  - Type/application-specific interfaces
  - General DDS API
- Applications use these generated python classes to pub/sub
- Issues:
  - Wrappings are type/application-specific
  - Requires extra steps outside of Python to generate the bridge objects
  - When topic definition changes, need to re-generate all the bridging objects and the application codes
  - *Disruptive to Python's dynamic/interpretive language* features
- Solutions: A generic Python DDS bridge implementation

Tech-X Implemented an Architecture for a Generic Python DDS Bridge



Our Approach Allows Dynamic Generation of Python Topic Code

- Import PyDDS as a python module into Python application codes
  - We are aware of another PyDDS implementation from Github: https://github.com/forrestv/pyDDS
- Dynamically generate topic-specific DDS classes using services provided by PyDDS
- Interact with DDS subsystem directly via PyDDS and the generated topic-specific objects
- Benefits:
  - No need to use tools outside of Python
  - No need to re-generate Python bridges when IDL changes
  - More natural Python application development flow

PyDDS Relies on Boost.Python, Python and OpenSplice

Key components fall into 3 main categories:

- General DDS API
  - Managing various entities and built-in data types (DomainParticipant, Publisher/Subscriber, QoS, WaitSet, etc.)
- Type management facility
  - Internalizing type definitions
  - Generating typed objects
- Type specific API
  - DataReaders/DataWriters
  - Listeners*

Current Status

- Implementation based on OpenSplice Community Edition version 5.4.1/5.5.1
  - Linux and Windows platforms
  - With stock Python installation 2.6 or later
  - Boost library is optional for end-users
- Supports for simple topic types using IDL
  - All basic types and strings
- Supports for programmatic construct of topic types
- Simple read/write
- WaitSets/Conditions
- Listener callbacks
- Some support for SimD-like abstractions

General DDS Entity Example: Joining a data domain/partition

```
# A one-stop interface into the pydds global factory methods
import PyDDS;
pydds=PyDDS.PyDDS()
dp=pydds.create_participant("")   # DomainParticipant Factory
publisher=dp.create_publisher(publisherQos)


# For higher abstraction, PyDDS defines a default dataspace object.
# It can be explicitly instantiated or generated by PyDDS with
# default (nameless, partitionless) dataspace automatically.
# A Dataspace object can instantiate default subscriber/publisher
# objects with default QoS policies automatically on demand.

myDataspace
   = pydds.connect_dataspace
         ("Domain name", "Partition name")
dp=myDataspace.get_participant()
publisher=myDataspace.get_publisher()
```

General DDS API Example: Manipulating QoS Policy Sets

```
# Instantiate QoS objects and manipulating them using
# standard entity calls for QoS policy manipulations
# and some SimD-like calls
publisherQos=pydds.PulisherQos()
publisher.get_default_publisher_qos(publisherQos)
publisherQos.set_partition("Example Partition")


myTopicQoS = pydds.TopicQos()
myTopicQoS.set_reliable()
myTopicQoS.set_transient()
myTopicQoS.set_keep_last (3)
```

Topic Type Definition Management Examples

- Parsing IDL Files

```
# Getting a hold to the Type Manager
idlFilePath=os.getcwd()+'/HelloWorld.idl'
ddsTypeManager=pydds.get_type_namager()
ddsTypeManager.parseIDL(idfFilePath)
```

- Or, Constructing a type programmatically

```
# Creating a Type Factory
typebuilder=ddsTypeManager.DDSTypeFatory(['module','list'],'topic name', sourceURL)
typebuilder.add_primitive(DDSTYPES_LONG, 'userID')
typebuilder.add_primitive(DDSTYPES_STRING, 'message')
typebuilder.add_keys(['userID'])
helloWorldMetaClass = typebuilder.complete_type()
```

- Current status
  - Support all primitive types and strings
  - Need supports for sequences, arrays, nested structs

Using the Topic Type Metaclasses

- Get a hold of a metaclass and inquire about the type information

```
# acquire the metaclass object from the type manager
helloWorldType=ddsTypeManager.getTypeByName('HelloWorldData::Msg')
topicTypeName=helloWorldType.pydds__getTypename()
keyStr=helloWorldType.pydds__getKeys() # Comma-separated keys
```

- All type-specific operations use type metaclasses

```
# Create an object instance of the type
helloWorld = helloWorldType()
helloWorld.userID=1001
helloWorld.message='Hello World'
# Create a sequence of HelloWorld Objects
helloWorldSeq=pydds.ObjectSeq(helloWorldType)
helloWorldSeq[0].userID=1002
helloWorldSeq[0].message='Hello again!'
```

- Similarly, registering the type definition with DDS

```
dp.register_type(helloWorldType, topicTypeName)
```

Type-specific Operation Examples: Create Topics, Readers, Writers

```
# Creating/Finding a topic in the data space
# Last argument specifies the URI of the topic structure
helloTopic = dp.create_topic('HelloWorld_Msg', topicTypeName,
HelloWorldTopicQos)

# Creating topic-specific reader/writer:
helloReader = subscriber.create_reader (helloTopic, readerQoS)
helloWriter = publisher.create_writer (helloTopic, writerQoS)
```

More Type-specific Operation Examples: Simple Writing and Reading DDS Samples

```
# creating a sample
helloSample=helloWorldType()
helloSample.userID=1001
helloSample.message="Wow!"
# publishing the sample
status = helloWriter (helloSample)

# Simple read is straightforward
sampleSeq=pydds.ObjectSeq(helloWorldType)
infoSeq = pydds.SampleInfoSeq()
status=helloReader.take(sampleSeq,
                        infoSeq,
                        pydds.LENGTH_UNLIMITED,
                        pydds.ANY_SAMPLE_STATE,
                        pydds.ANY_VIEW_STATE,
                        pydds.ANY_INSTANCE_STATE)
```

Building a WaitSet Example

```
# creating a WaitSet object
myWaitSet=pydds.WaitSet()

termCond=pydds.GuardCondition()
newMsgCond=helloReader.create_readcondition
   (pydds.NOT_READ_SAMPLE_STATE, pydds.ANY_VIEW_STATE,
    pydds.ALIVE_INSTANCE_STATE)
wrtrCond=helloReader.get_statuscondition()
wrtrCond.set_enabled_statuses(pydds.LIVELINESS_CHANGED_STATUS)
myWaitSet.attach_condition(termCond)
myWaitSet.attach_condition(newMsgCond)
myWaitSet.attach_condition(wrtrCond)

# Waiting and Acting on Waitsets
condList=pydds.ConditionSeq(3)
timeout=pydds.Duration(3,0)
myWaitSet.wait(condList, timeout)
```

Using A WaitSet Example

```
# Waiting and Acting on Waitsets
condList=pydds.ConditionSeq(3)
timeout=pydds.Duration(3,0)
myWaitSet.wait(condList, timeout)
for i in range(len(condList)):
    if (termCond.is_same_condition(condList[i]):
        # Handle terminate signal
    elif (newMsgCond.is_same_condition(condList[i]):
        # Handle new sample available
    elif (wrtrCond.is_same_condition(condList[i]):
        # Handle writer joining/leaving
    else:
        # something is wrong….

# Cleaning up
myWaitSet.detach_condition(wrtrCond)
…
```

Simple Event-based Listener Examples

- PyDDS *provides several "listener objects" for calling Python* callback functions

```
# Getting a hold to a DataReaderListener
exListener=pydds.DataReaderListener()
```

- Implementing Python callbacks as functions

```
def data_handler(reader):
    dataSeq=pydds.ObjectSeq(helloWorldType)
    infoSeq=pydds.SampleInfoSeq()
    reader.read(dataSeq,infoSeq,…) # No need to downcast!!
    …
exListener.set_on_data_available(data_handler)
# each callback can be set separately
listenerMask=pydds.DATA_AVAILABLE_STATUS |
             pydds.REQUESTED_DEADLINE_MISSED
helloReader.set_listener(exListener, listenerMask)
```

More Event-based Listener Examples

- Alternative, implement a set of related callbacks as member functions in a class

```
class appEventLogic:
    def __inti__(self,more_args):
        # define and initialize internal states
    def deadline_missed(self, reader, status):
        …
    def liveliness_changed(self,reader, status):
        …
    def newdata(self,reader):
        …

applicationLogic=appEventLogic(more_args)
exListener.set_on_deadline_missed(lambda r,s:
           applicationLogic.data_handler(r,s))
exListener.set_on_data_available(lambda r:
           applicationLogic.newdata(r))
```

Example Applications under Developments

- The flying shape example using Pygame
  - Show interoperability with other DDS implementations
- HPC/multi-physics simulation monitoring/steering applications
  - Tech-X has vast expertise in high-performance, heterogeneous, parallel, multi-physics simulations
  - *Python's fast prototyping capability often helps* integrating these computational/simulation modules
  - Similarly, Python has shown to help GPU/OpenCL kernel development by handling all the error-prone, architecture dependent configuration code
  - Coupled with DDS, we can provide monitoring and steering capabilities to real-time data processing

For more information, please visit: http://www.txcorp.com/

Conclusion and Future Work

- DDS for Python marries two robust and dynamic technologies
- Currently, we support most key DDS features over OpenSplice Community Versions but leverage key Python dynamic language features
- Will be available soon
- Further work includes:
  - Support for most standard API
  - Support for compound data types

Please come to see our talk on scientific DDS applications
During *OpenSplice's* Users Meeting

Future Work: Enhancing PyDDS API

- Provide Higher-level of abstractions
  - Better dataspace support
  - Configuration can be done outside the code using XML files
  - Waitset abstraction – automatic clean up and traversal dispatch of handlers
  - Single handler class support for Listeners
    - Allow whole-sale replacement of all listener callbacks
- Enhance Python API
  - Borrow more from the new C++ PSM
    - Allow tweaking QoS with a list of policy objects

      ```
      tqos.set([History.keep_last(3), Reliability.Reliable()])
      ```
  - More Pythonism
    - More use of exceptions
    - E.g., read operations can return a tuple

      ```
      (dataSeq, infoSeq) = reader.read(max_length, conditions)
      ```