Ongoing Efforts

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CRAY CHAPEL

Outline

- [Constrained Generics]()
- ['ofi' Comm Layer]()
- [Shasta Chapel Module]()

Constrained Generics

Background: Generics in Chapel

- Today, the Chapel compiler follows the C++ strategy for generics
  - generic functions are instantiated and then type-checked
- However, this approach presents several problems:
  - generic code might not compile for all calls, with potentially confusing errors
  - long compile times
  - confusing point-of-instantiation rule
- Currently requires complex where-clauses for simple argument constraints
  - e.g., "the argument should be iterable and yield strings"
  - "the argument should have a 'this' method"

Goals of Constrained Generics

- Constrained generics enable more expressive programs
  - Allow users to indicate requirements of function interfaces more cleanly

```
proc foo(arg: ?T) where T implements Iterable(int) { ... }
```

- Can help improve point-of-instantiation
- Might help with compile-time issues
  - indicate requirements in generic function prototypes
  - type-check generic functions before instantiation
  - instantiate generic functions later in compilation

Unconstrained Generic

```
proc double(arg: ?t): t {
  writeln("2x ", arg.show());
  return add(arg, arg);
}
```

```
proc int.show(): string {
  return "int " + this:string;
}
```

// instantiates with 't' replaced by 'int'

// functions from point-of-instantiation are in scope

```
proc double(arg: int): int {
  writeln("2x ", arg.show());
  return add(arg, arg);
}
```

```
proc add(a: int, b: int): int {
  return a + b;
}
```

```
double(1);
```

Unconstrained Generics and Visibility

```
module Lib {
```

point-of-instantiation rule

```
  proc genericFunction(arg) {
    foo(arg);
  }
}
```

```
module Main {
  use Lib;
  proc foo(arg: int(8)) {
    writeln("Lib.foo(int(8))");
  }
  proc foo(arg: int) {
    writeln("Lib.foo(int)");
  }
  proc main() {
    var x = 1:int(8);
    genericFunction(x);
  }
}
```

CHIP 2 Constrained Generic

```
proc double(arg: ?t): t
where t implements Doubleable {
  writeln("2x ", arg.show());
  return add(arg, arg);
}
```

// can resolve 'double' without instantiating

```
interface Doubleable {
  [0]: proc self.show(): string;
  [1]: proc add(a: self, b: self): self;
}
```

```
int implements Doubleable {
  proc int.show(): string {
    return "int " + this:string;
  }
  proc add(a: int, b: int): int {
    return a + b;
  }
}
double(1);
```
// can quickly check for errors

// can use internal table to easily instantiate later

```
implementation Doubleable(int):
  [0]: show
  [1]: add
```

Constrained Generics and Visibility

```
module Lib {
  interface I {
    proc foo(arg: self);
  }
  proc foo(arg:int(8)) {
    writeln("Lib.foo(int(8))");
  }
  proc genericFunction(arg: ?t)
  where t implements I {
    foo(arg);
  }
}
```

```
module Main {
  use Lib;
  proc foo(arg: int) {
    writeln("Main.foo(int)");
  }
  int implements I;
  int(8) implements I; // overload sets error?

  proc main() {
    var x = 1:int(8);
    genericFunction(x);
  }
}
```

High Level Design Questions

- Some questions are less contentious, or easier to change with feedback
  - What is the terminology, syntax, and style to use?
  - Do we support both methods and function calls?
  - Can the compiler infer implementation of an interface?
- Others have less certainty, but aren't critical decisions
  - Can one assert an interface is met separately from an 'implements' block?
  - How can functions with the same name be handled?
- A major critical decision remains
  - How will the language handle generic functions without constraints?

Functions Without Constraints

Unconstrained Generics

- How will the language handle generic functions without constraints?
  - Such generic code is very common in Chapel today

```
proc double(arg) { return arg + arg; }
```

- Potential strategies for resolving constrained and unconstrained generics:
  1. Resolve them both late — after instantiation
  2. Resolve them both early — before instantiation
  3. Use hybrid strategies
  4. Disallow unconstrained generics
     - Not really under consideration as it would prevent script-like code

Resolving Them Both Late

- In this approach, a constraint on a generic would serve as extra type-checking
- It would not affect which functions are resolved

Pros:

- Easiest strategy to implement
- No language changes for unconstrained generics
- Constrained and unconstrained generics have similar visibility rules

Cons:

- does not help with complete type-checking of generic code
- does not replace the point-of-instantiation rule
- will not improve compile times or reduce the amount of type-checking

Resolve Both Early

- Here, unconstrained and constrained generics would both resolve early
- Constrained generics would behave as described earlier
- Unconstrained generics would become more similar to constrained generics
  - compiler would infer both interface and 'implements' statements
  - then use constrained generic rules for function visibility

Resolve Both Early: An Example

```
proc double(arg: ?t): t {
  writeln("2x ", arg.show());
  return add(arg, arg);
}
```

- Strategy: generate anonymous interface for 'arg'

```
interface double_arg_0 {
  proc self.show(): Writable;
  proc add(a: self, b: self): self;
}
```

- Could it furthermore type-check while building up this list of constraints?

```
proc int.show(): string {
  return "int " + this:string;
}
proc add(a: int, b: int): int {
  return a + b;
}
// Could compiler infer that the constraint is met?
double(1);
```

Resolve Both Early: Challenges

- Supporting common patterns in generic code will require additional effort
  - compile-time conditionals, e.g. 'if t == string then ...'
    - would require compile-time evaluation while resolving the interface
    - might lead to groups of interfaces, or conditionals *in* interfaces
  - inferred variable and return types

```
// potentially three anonymous interfaces
var x = arg.foo(); var y = x.bar(); return y.baz();
```

  - generic varargs, param loops

Resolve Both Early: Graph of Constraints

- One possibility: construct a graph combining constraints and type inference
  - Significantly more complicated than other strategies, likely prone to bugs
  - Unknown impact on compile-time to create and evaluate such graphs
- Error messages for such graphs may not be an improvement over today
  - Error messages for complex graphs might need to show a 'callstack'
  - Could the spec and compiler clearly communicate...

    ... how a graph/interface was built?

    ... how a graph/interface was evaluated?

Resolve Both Early: Summary

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Pros:

- Clear path for mixing constrained, unconstrained arguments/functions
- Potential to improve compilation speed for unconstrained generics

Cons:

- Supporting type inference will require significant implementation effort
- Unknown impact on compilation speed for unconstrained generics
- Changes visibility rules for unconstrained generics in existing code
- Error messages for anonymous interfaces may be no better than today

Hybrid Strategies

Resolve constrained generics before instantiation, unconstrained generics after

Pros:

- Limits changes for existing generic code
- Compilation speed improvements with early type checking
  - Could require use of constraints in standard/internal libraries

Cons:

- Mixing constrained and unconstrained generics will require special attention
- Does not improve compilation speed for unconstrained generics
- Different visibility rules between the two might be confusing

Unconstrained Generics: Summary

- "Both Late": least amount of effort for additional type checking

- "Both Early" and "Hybrid" offer potential compile-time improvements
  - Unknown or non-existent compile-time improvements for unconstrained
- "Both Early" unifies visibility, "Hybrid" requires more user attention

- "Both Early" has impact on existing programs with unconstrained
  - changes visibility rules
  - might not help compile-times or error messages
  - "Hybrid" has minimal impact by comparison

Unconstrained Generics: Next Steps

- Intend to pursue the hybrid strategy
  - More confident in implementation (timescale, maintenance, stability)
  - Allows for compilation time improvements
  - Minimal impact on existing programs
- Address open questions around hybrid strategy
  - Difference in visibility rules between constrained and unconstrained
  - How constrained and unconstrained would interact between/inside functions
- Path to "both early" option still remains open going forward

Hybrid Strategy: Open Questions

- How to address the difference in visibility rules?
  - Better compiler error messages?
  - Alter unconstrained rules for common cases, if the impact is acceptable?
- Explore how to handle interaction between constrained and unconstrained
  - Require a function to have all arguments constrained or all unconstrained?
  - Calling unconstrained functions inside constrained functions?
    - Could disallow such calls as an easy-to-remember rule
  - Or fall back on late resolution when strategies mix?
- Should users have a way to require usage of constrained generics in a module?

Hybrid Strategy: Open Questions (cont.)

- Interaction with class management?
  - Could choose to treat arguments as 'borrowed' in absence of annotation

```
// currently has generic management
proc foo(arg : MyClass)
// could treat as 'borrowed' to allow both classes and records
proc bar(arg : Writable)
```

Other Design Questions

High Level Design Questions

- Some questions are less contentious, or easier to change with feedback
  - What is the terminology, syntax, and style to use?
  - Do we support both methods and function calls?
  - Can the compiler infer implementation of an interface?
- Others have less certainty, but aren't critical decisions
  - Can one assert an interface is met separately from an 'implements' block?
  - How can functions with the same name be handled?
- A major critical decision remains
  - How will the language handle generic functions without constraints?

Asserting an interface is met

- In Rust, 'implements' blocks always contain the implementation
- Compare with CHIP 2, which allows a statement like

```
int implements Doubleable;
```

- Even in Rust, the functions defined in an 'impl' are visible outside of the trait
  - so 'impl' block requirement is not due to visibility requirements
- Even if implementations must be in an 'implements' block, one could forward:

```
proc myAdd(a: int, b: int): int { ... }
int implements Doubleable {
  proc add(a: int, b: int): int { return myAdd(a, b); }
}
```

- Standalone 'implements' has low design impact, avoids duplicate methods

CHIP 2 Constrained Generic: Separate Clause

```
interface Doubleable {
  proc self.show(): string;
  proc add(a: self, b:self): self;
}
proc double(arg:?t):t
where t implements Doubleable {
  writeln("2x ", arg.show());
  return add(arg, arg);
}
```

```
proc int.show():string {
  return "int " + this:string;
}
proc add(a: int, b: int): int {
  return a + b;
}
int implements Doubleable;
double(1);
```

Handling Duplicate Function Names

- Sometimes generic code might use two interfaces with the same function names

```
interface Addable {
  proc self.accum(other: self): self;
}
interface AccumAble {
  proc self.accum(other: self): self;
}
proc double(arg: ?t)
where t implements Addable && t implements AccumAble {
  arg.accum(arg); // ambiguous: which accum?
}
```

Handling Duplicate Function Names

- How can one resolve the ambiguity?
  - Could decorate functions with interface name, e.g., 'Doubleable.add(arg, 1)'
  - Could allow renaming in 'implements' statements, e.g.,

```
where t implements Addable with accum as accumA, Sumable
```

  - Could allow a cast syntax, e.g., '(arg: Addable).accum()'
  - Or could require a wrapper method:

```
proc doubleableShow(arg: Doubleable) { arg.show(); }
doubleableShow(arg);
```

- Universal method syntax helps to enable this in Rust
  - 'arg.show()' can be written as 'show(arg)' - so e.g., 'Doubleable.show(arg)'

Terminology, Syntax, and Style Choices

- 'interface', 'trait', 'protocol', or 'concept' ?
- 'self' is the type being implemented by the constrained generic
  - Should it be explicitly named as an interface argument?
  - 'self' or 'Self' ? Should interface names be UpperCase or lowerCase?
- How exactly can one write a constraint on a generic argument?

```
proc f(arg: ?t) where t implements MyInterface // preferred
proc f(arg: ?t) where t: MyInterface
proc f(arg: implements MyInterface)
proc f(arg: impl MyInterface)
proc f(arg: MyInterface) // preferred
```

Method and Function Signatures in Interfaces

- CHIP 2 proposal uses the 'self' keyword to differentiate methods and functions:

```
proc add(a: self, b: self): self; // non-method
proc self.show(): string;         // method
```

- Alternatives:
  - Identify methods with 'this' as the method receiver:

```
proc this.show(): string;         // method
```

  - Indicate methods with 'this' as the first argument:

```
proc show(this): string;          // method
```

  - Use universal methods like Rust does:

```
proc show(_:self): string;        // show(1) works
proc add(a: self, b: self): self; // a.add(b) works
```

‘ofi’ Comm Layer

ofi Comm : Background, This Effort

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Background: Ongoing development of a libfabric-based comm layer

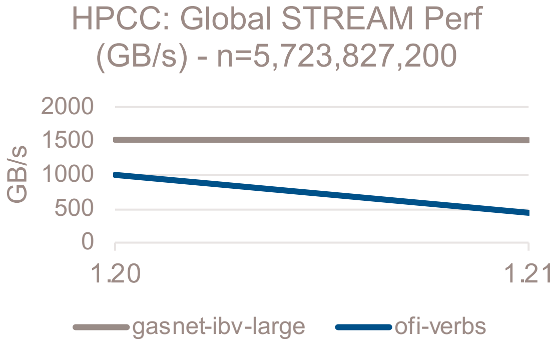
- In 1.20, passed most testing on all our targets with appropriate provider(s)
- Performance on par with gasnet but with slow cases, hangs, and variability

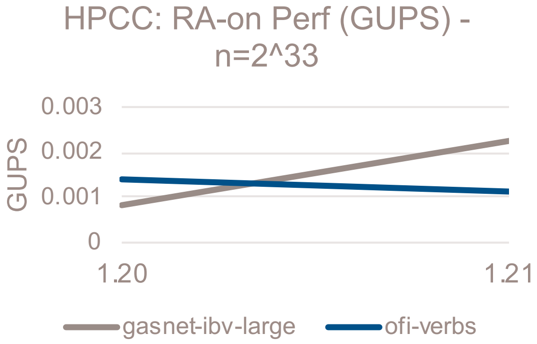
This Effort: Ongoing improvements

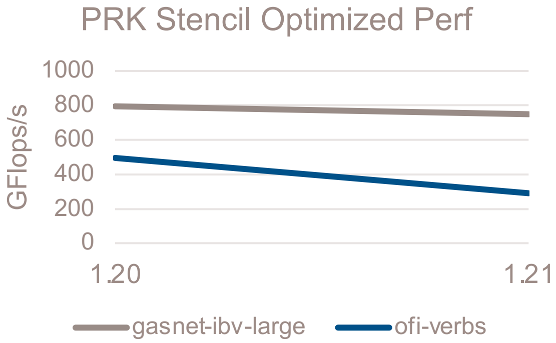
- Began nightly functional and performance testing
- Improved most slow cases
- Added unordered GETs, PUTs, AMOs
- Diagnosed all hangs; fixed all but one and have a plan for that one
  - One transaction progress fix caused widespread performance regression

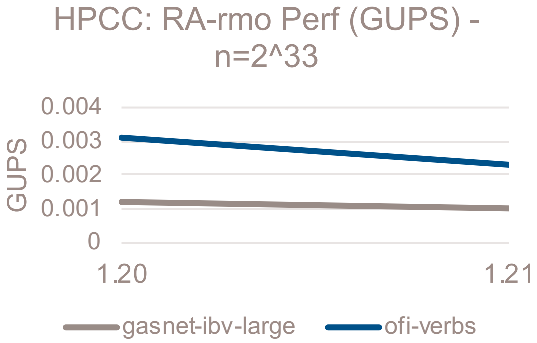
ofi Comm: Benchmark Performance

- 16-node Cray CS, InfiniBand network



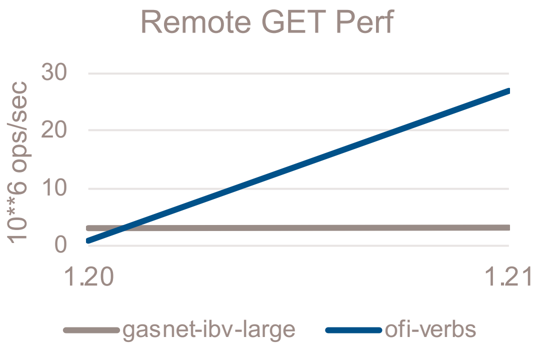


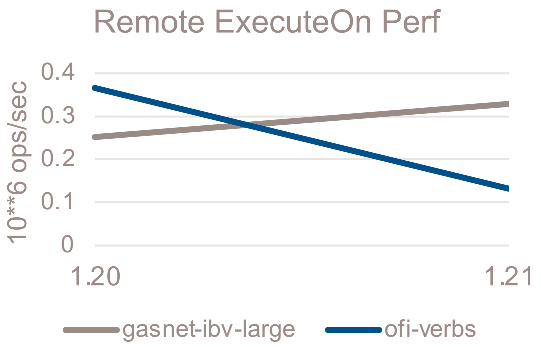


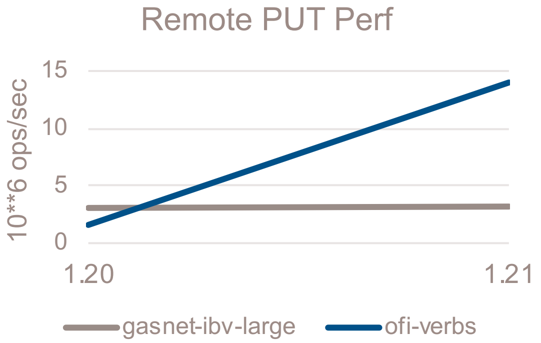


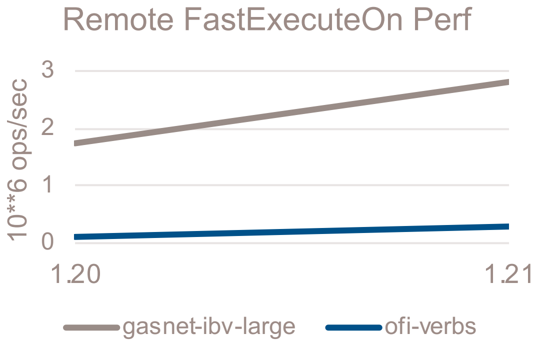
ofi Comm: Microbenchmark Performance

- 16-node Cray CS, InfiniBand network









ofi Comm: Next Steps

- Continue improving provider and platform portability

- Continue improving performance
  - Recover performance loss due to transaction-progress fix
  - Adjust memory consistency model (MCM) handling in compiler, modules

Shasta Chapel Module

Shasta Chapel Module

Background:

- Early-access Shasta customers had a pre-built Chapel from the start

This Effort:

- Normalized Shasta builds: removed special cases, cleaned up *ad hoc* logic

Status:

- Same 2 configs as in 1.20: comm=none and ofi, everything else default

Next Steps:

- Expand configurations to full supported set

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