Ongoing Efforts

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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

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

// 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); 
}

double(1); 
```

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

proc add(a: int, b: int): int { 
    return a + b; 
}
```
Unconstrained Generics and Visibility

module Lib {
    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

```haskell
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;
}
```

```haskell
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

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

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

• Strategy: generate anonymous interface for 'arg'
  ```haskell
  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?
  ```haskell
  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?
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

```plaintext
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)'

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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:

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

• Alternatives:

  • Identify methods with 'this' as the method receiver:

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

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

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

  • Use universal methods like Rust does:

    ```plaintext
    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

**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

[Graphs showing performance metrics for HPCC: Global STREAM Perf, HPCC: RA-on Perf (GUPS), PRK Stencil Optimized Perf, and HPCC: RA-rmo Perf (GUPS)]
ofi Comm: Microbenchmark Performance

- 16-node Cray CS, InfiniBand network

**Remote GET Perf**
- Gasnet-ibv-large: 10^6 ops/sec
- Ofi-verbs: 10^6 ops/sec

**Remote ExecuteOn Perf**
- Gasnet-ibv-large: 0.4 to 0.1
- Ofi-verbs: 0.3 to 0.1

**Remote PUT Perf**
- Gasnet-ibv-large: 0 to 3
- Ofi-verbs: 0 to 1

**Remote FastExecuteOn Perf**
- Gasnet-ibv-large: 0 to 1
- Ofi-verbs: 0 to 1
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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