facebook

GHC determinism

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Software Engineer, Facebook
Sep 24, 2016

What is *determinism*?

Determinism

- Given the same
  - Source
  - Flags
  - Environment
- Produce identical interface files
- Interface files determine ABI

Why is it important?

Build systems with remote caching

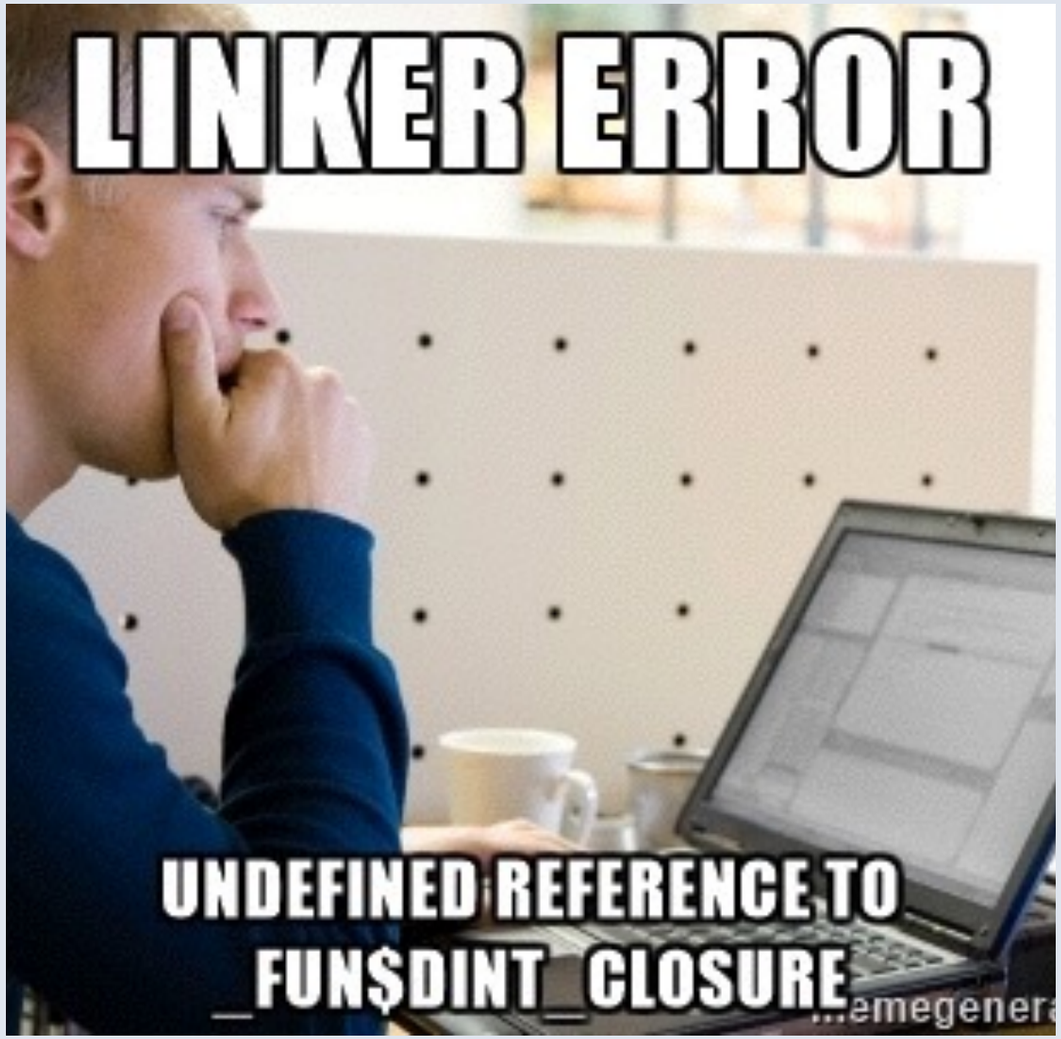
Buck, Bazel...

- Many developers and LOC
- Redundancy
- Idea:
  - Accurate dependency tracking
  - Minimal rebuilds
  - Shared cache

Build systems with remote caching

Buck, Bazel...

- Unfortunately things go horribly wrong with non-deterministic GHC



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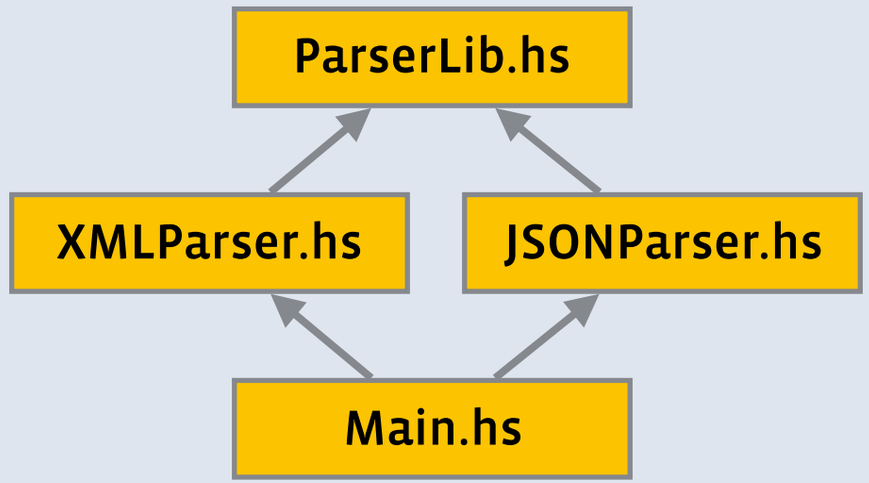

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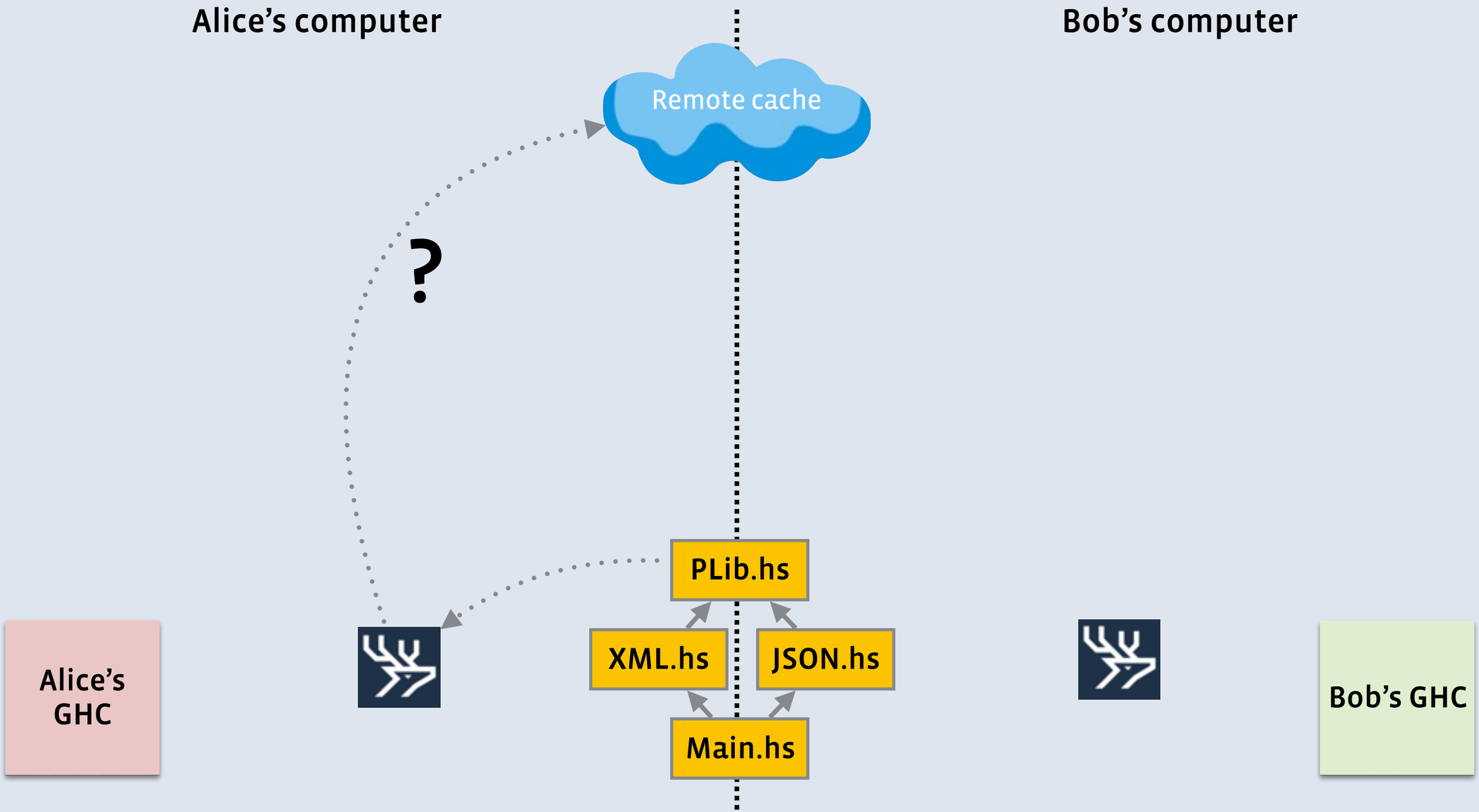
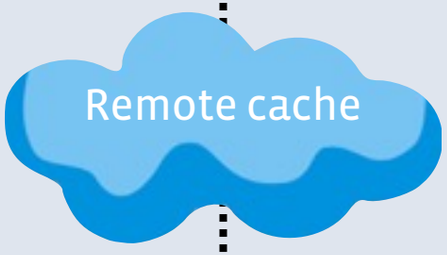


What happens if we try?

Alice's computer

Bob's computer



404

PLib.hs

XML.hs

JSON.hs

Main.hs

Alice's GHC

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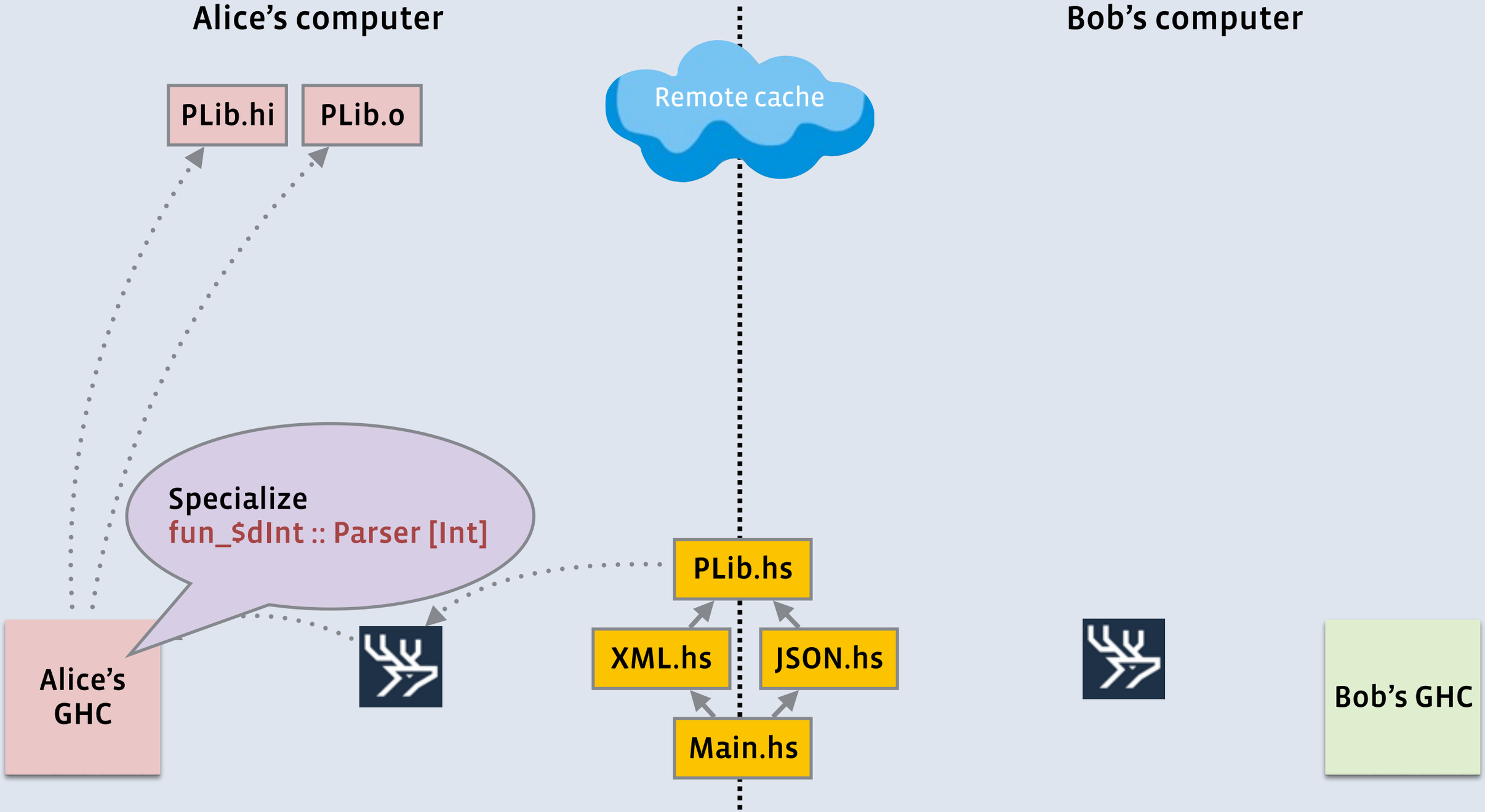

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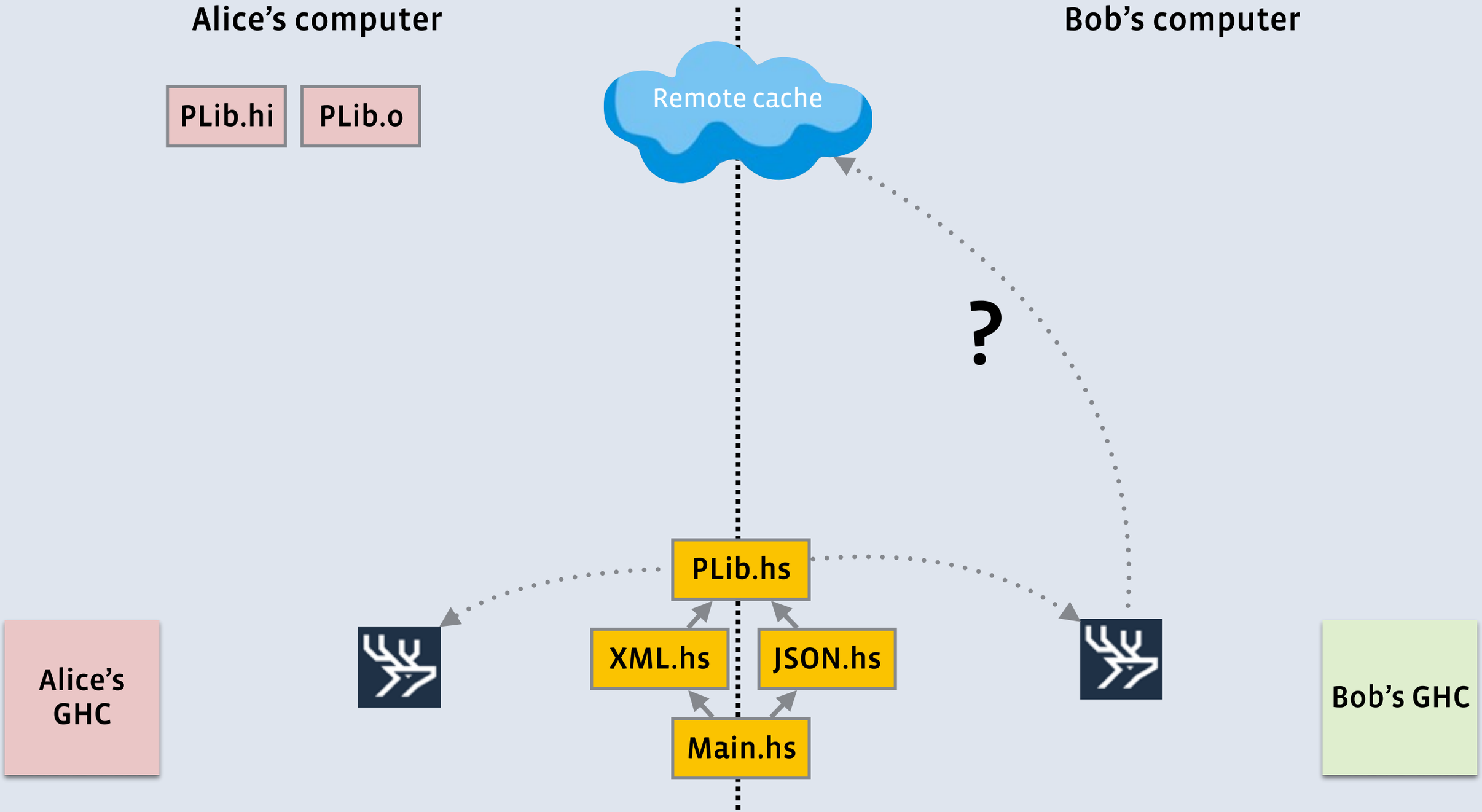

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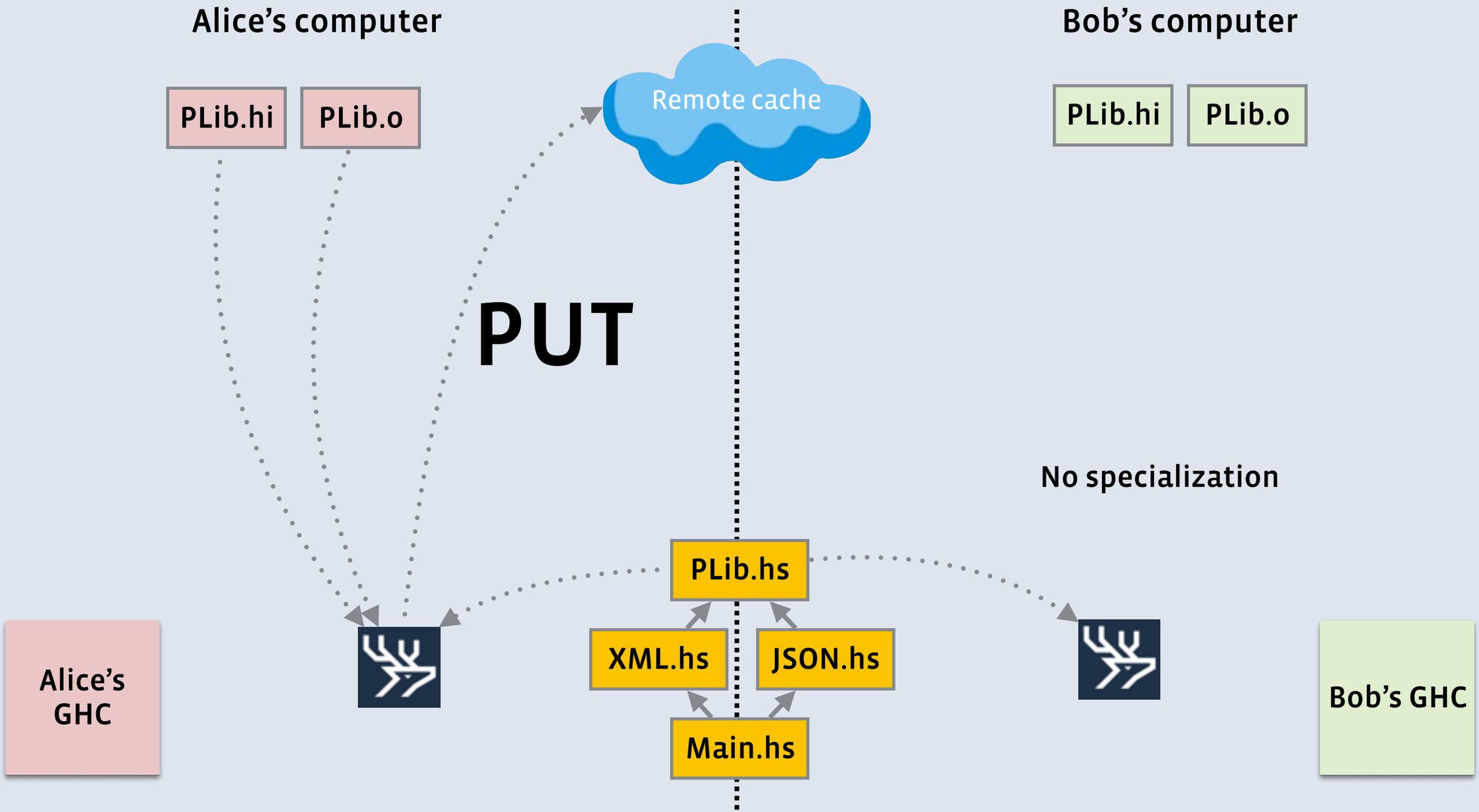

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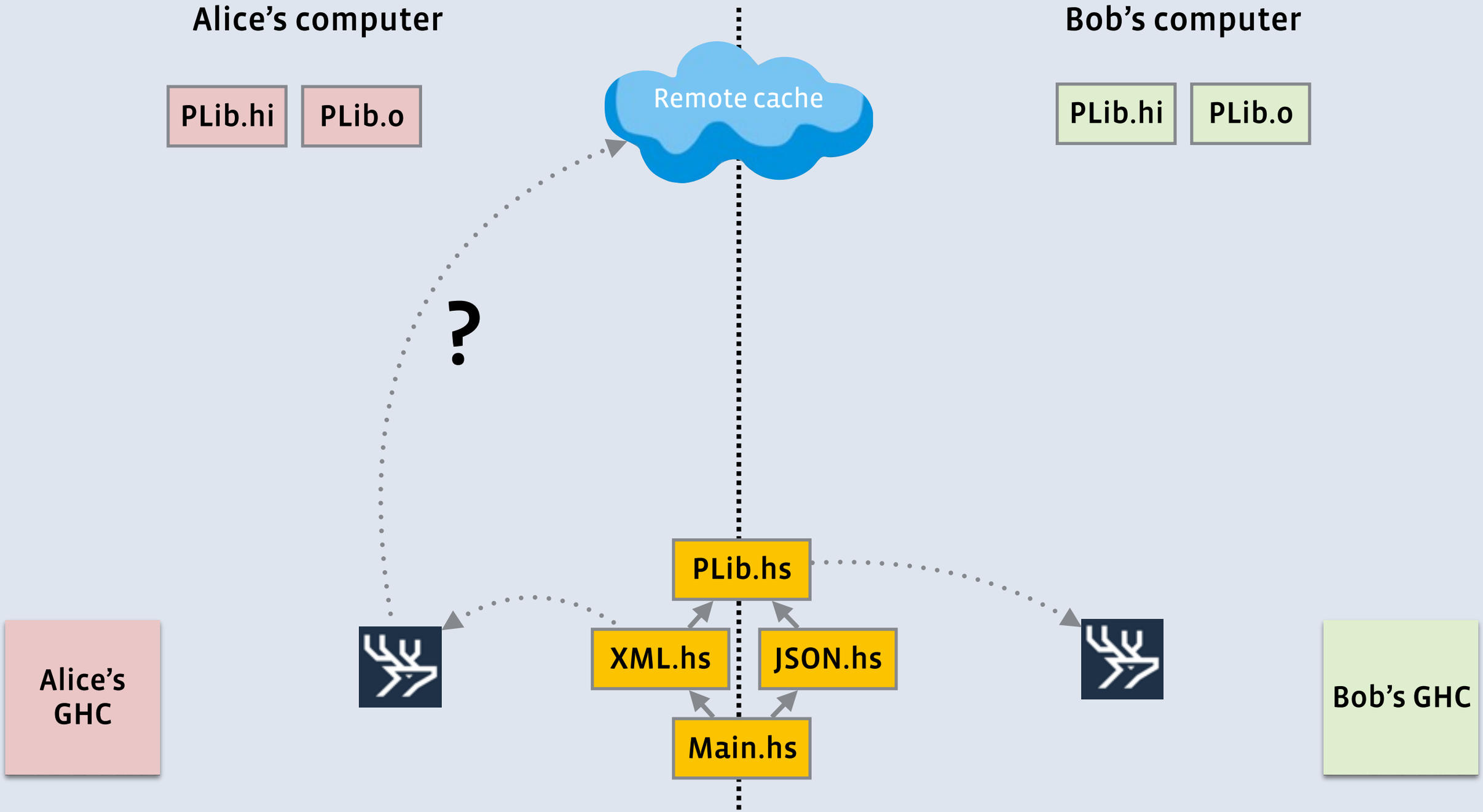

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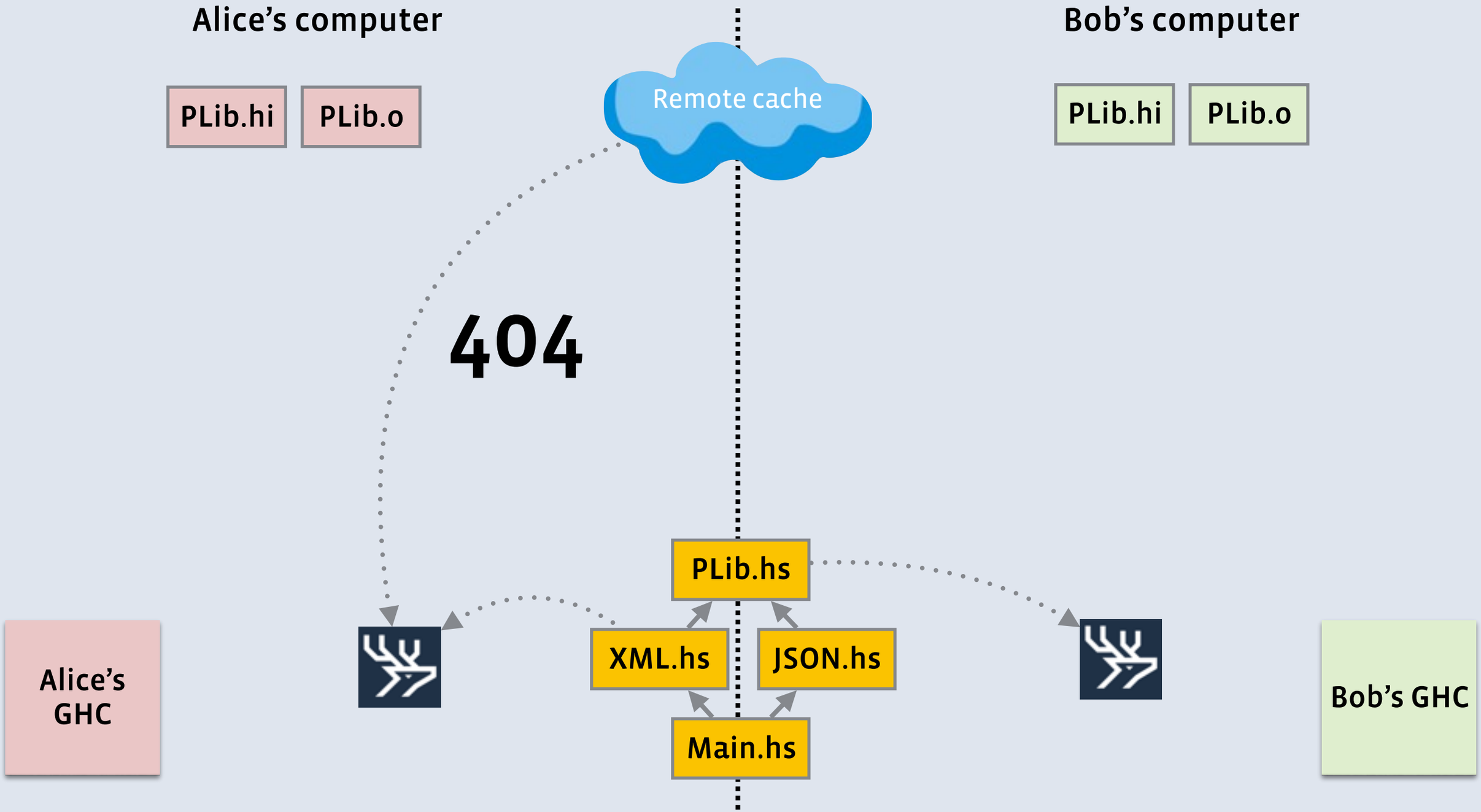

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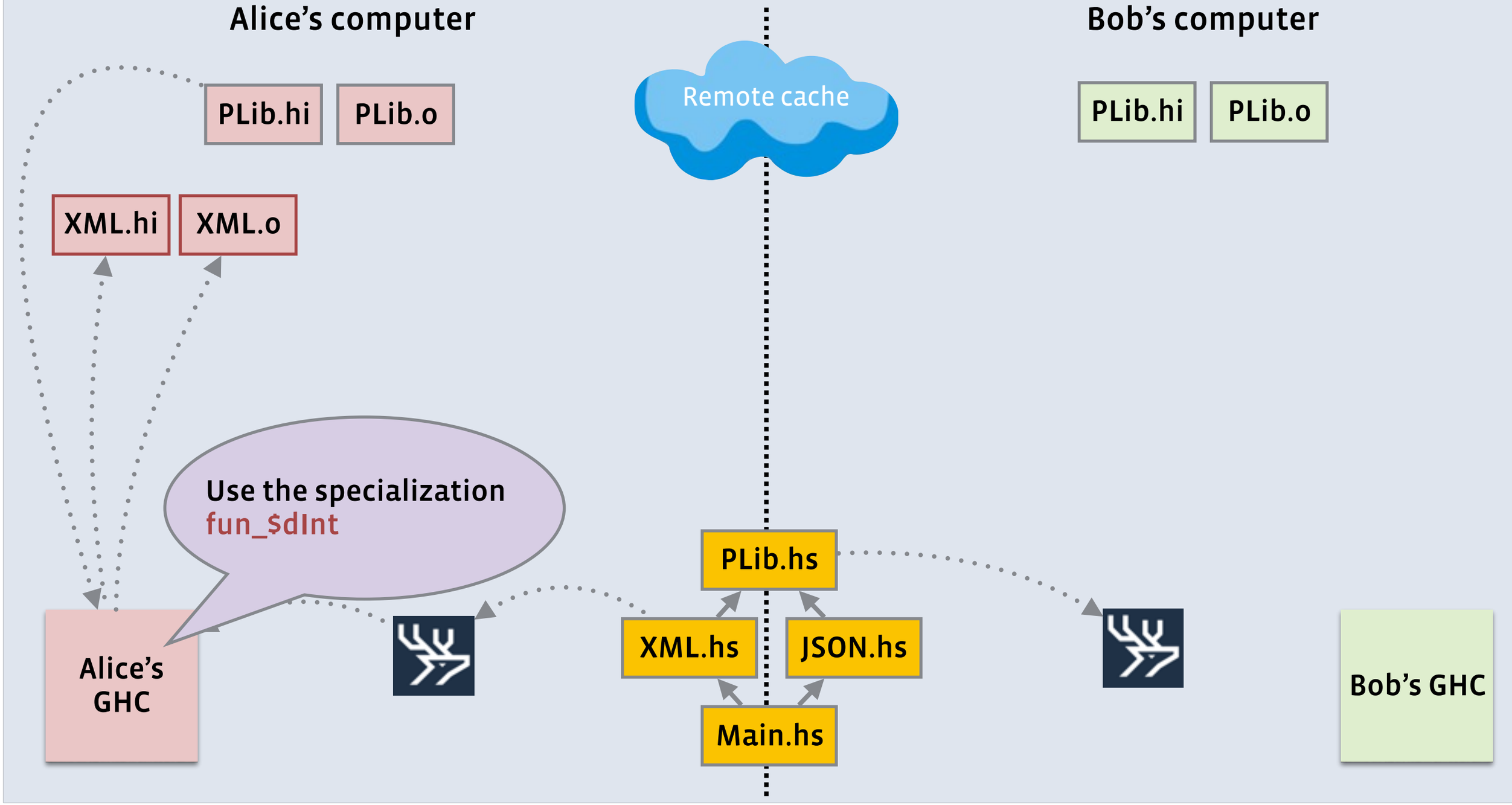

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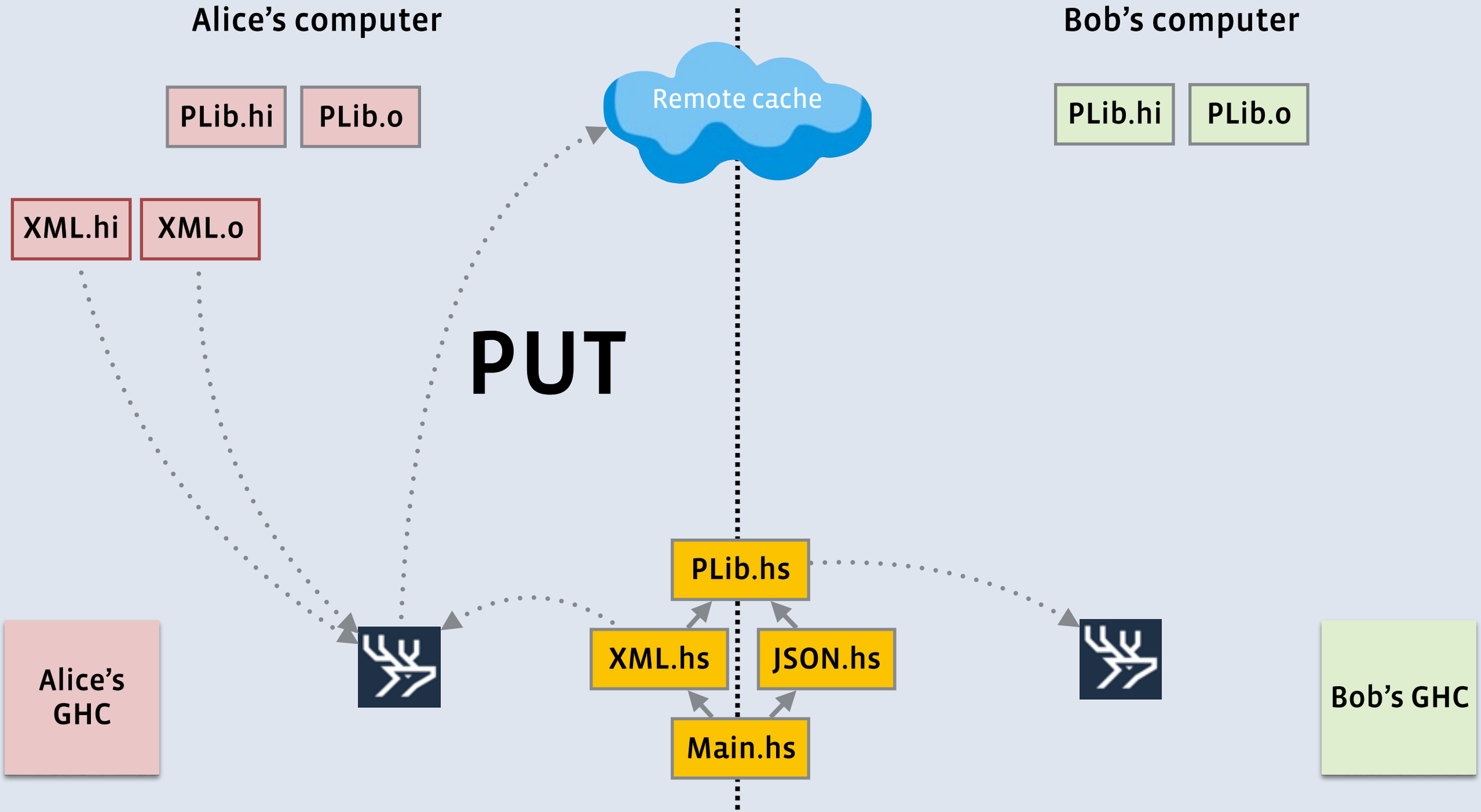

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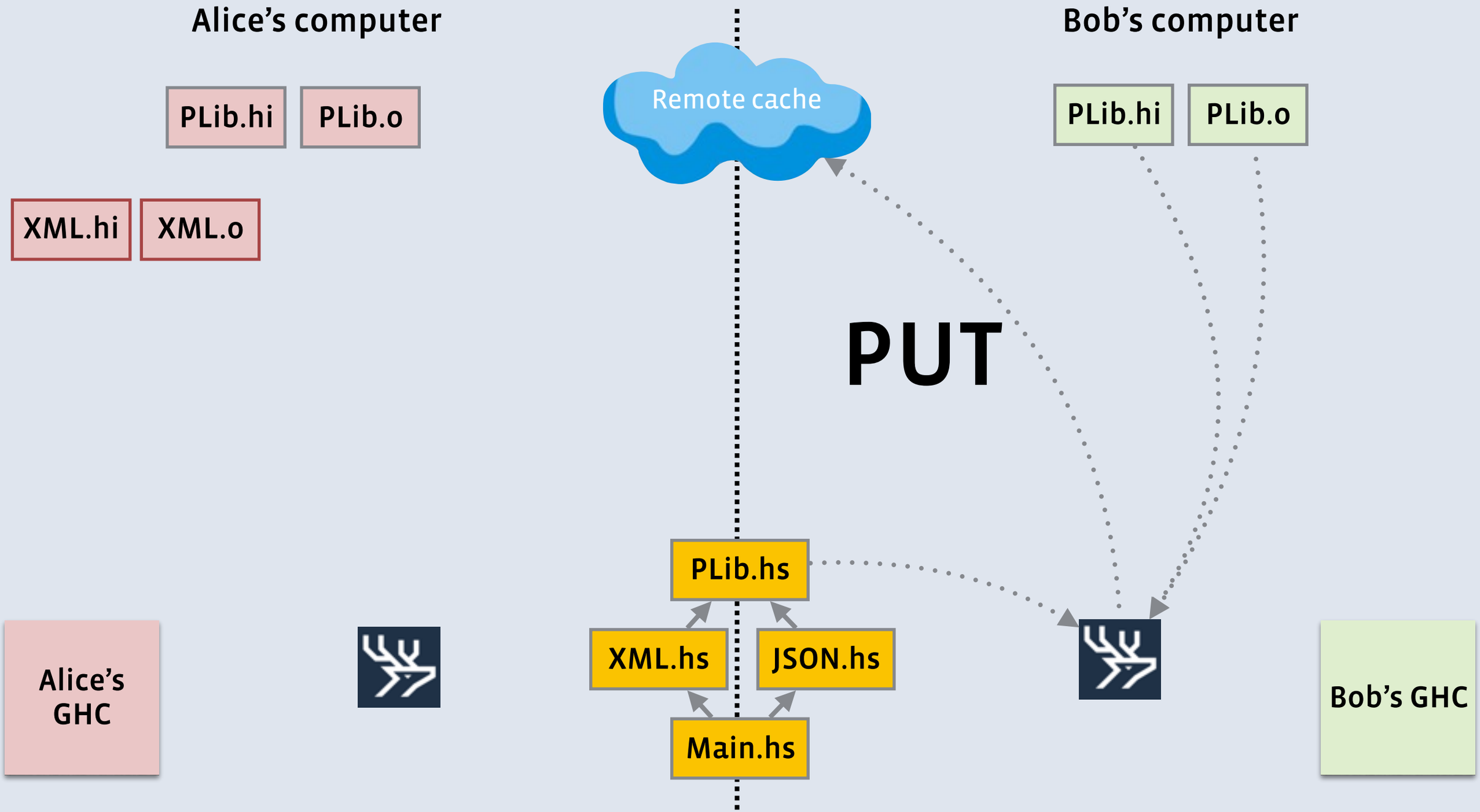

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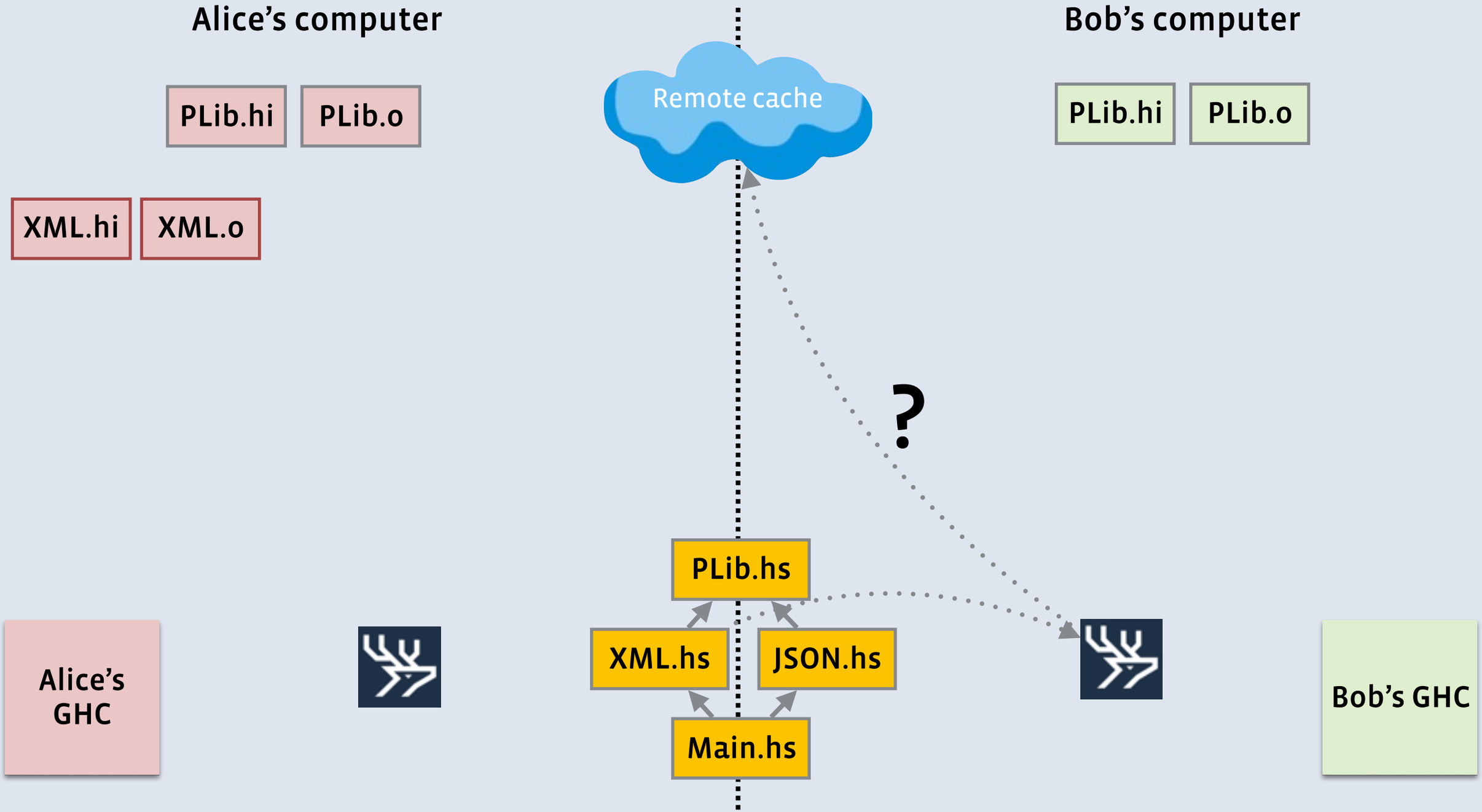

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HIT

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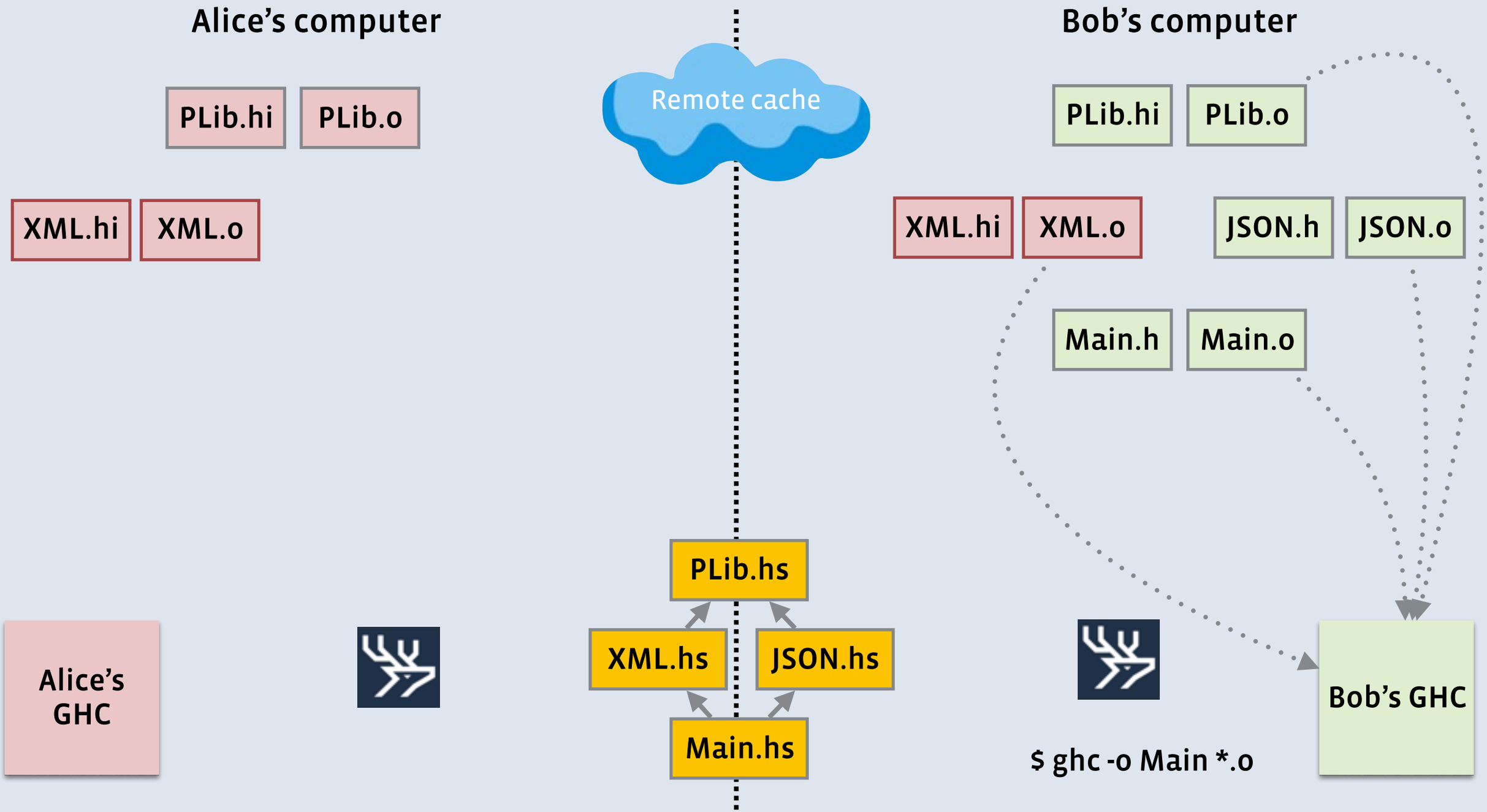


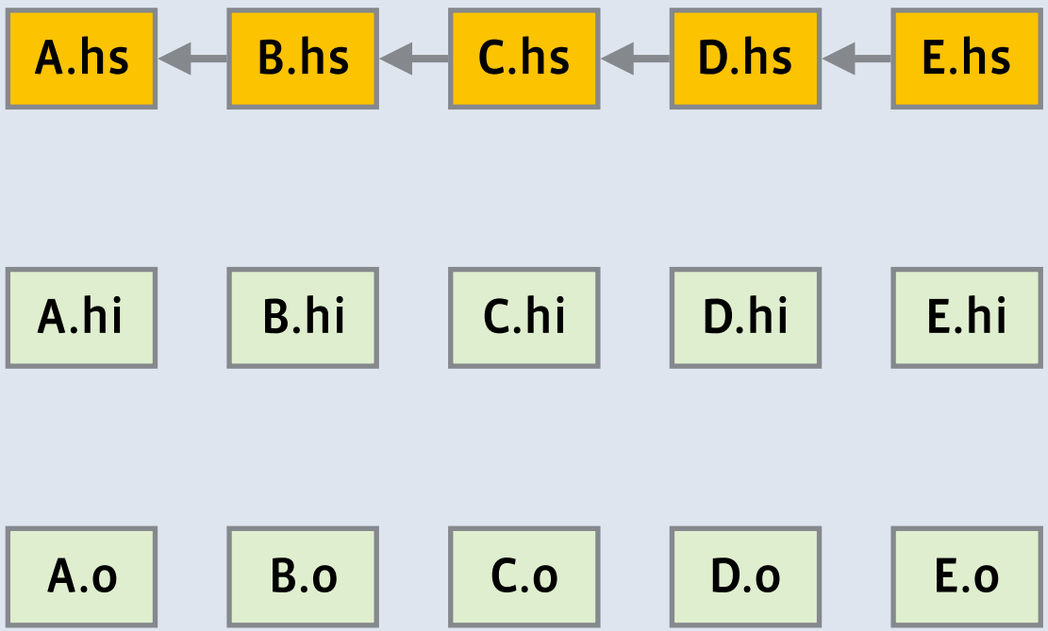
What happens if we try?

```
$ ghc -o Main *.o
Undefined symbols for architecture x86_64:
  "_ParserLib_commaSeparatedzudInt_closure", referenced from:
      _XMLParser_c_closure in XMLParser.o
ld: symbol(s) not found for architecture x86_64
clang: error: linker command failed with exit code 1 (use -v to see invocation)
```

Incremental builds

- Clean build can take a long time
- We want short feedback cycles
- Solution:
  - Minimal recompile
  - GHC has a recompilation check

Incremental builds



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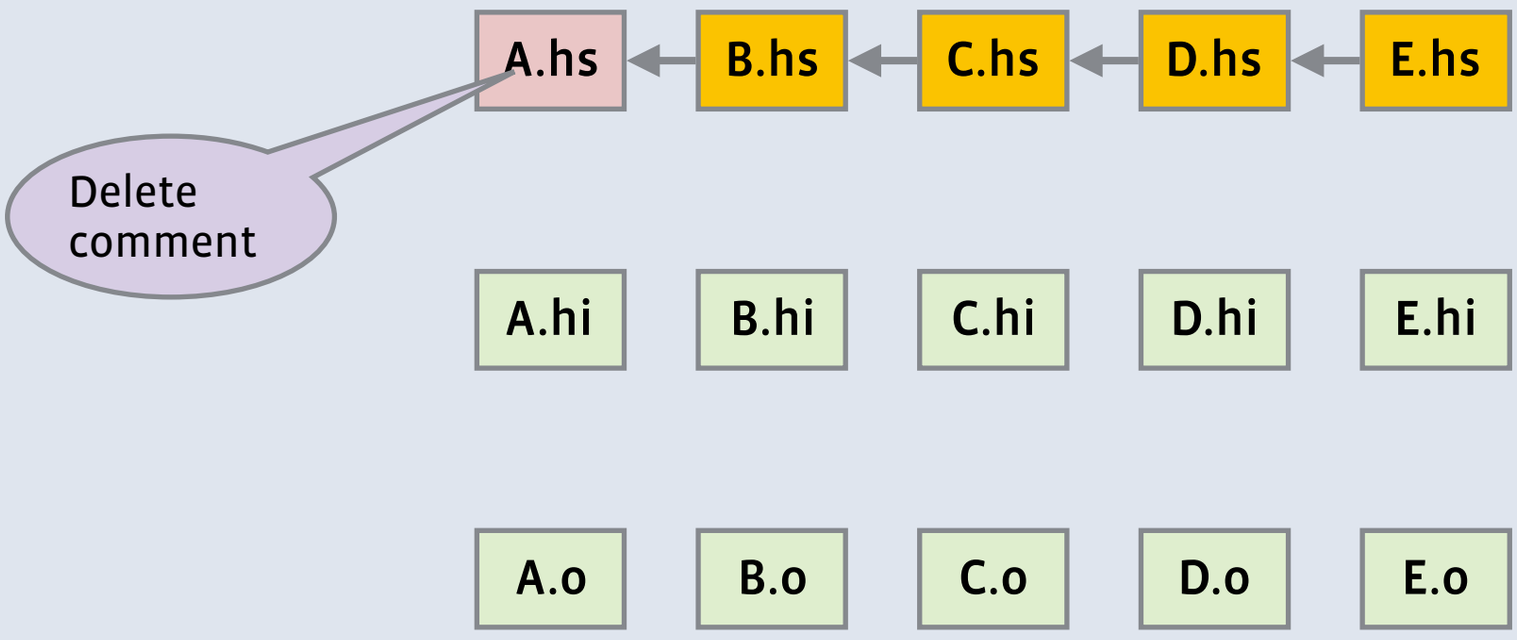

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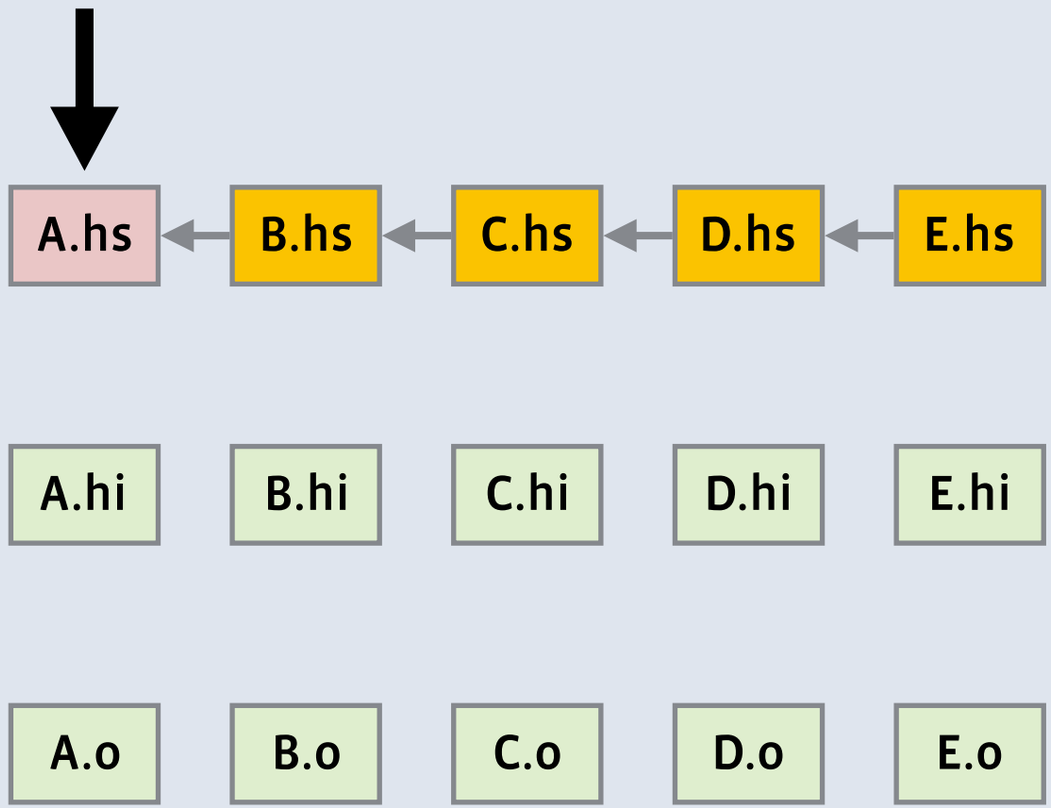

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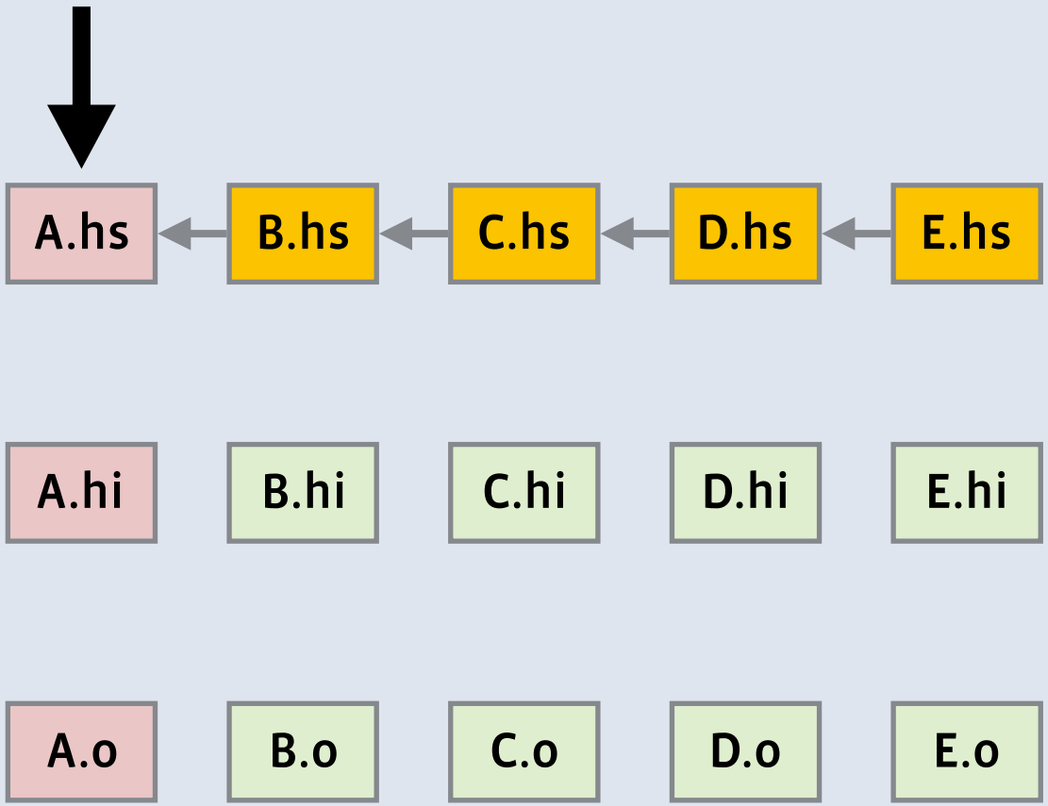

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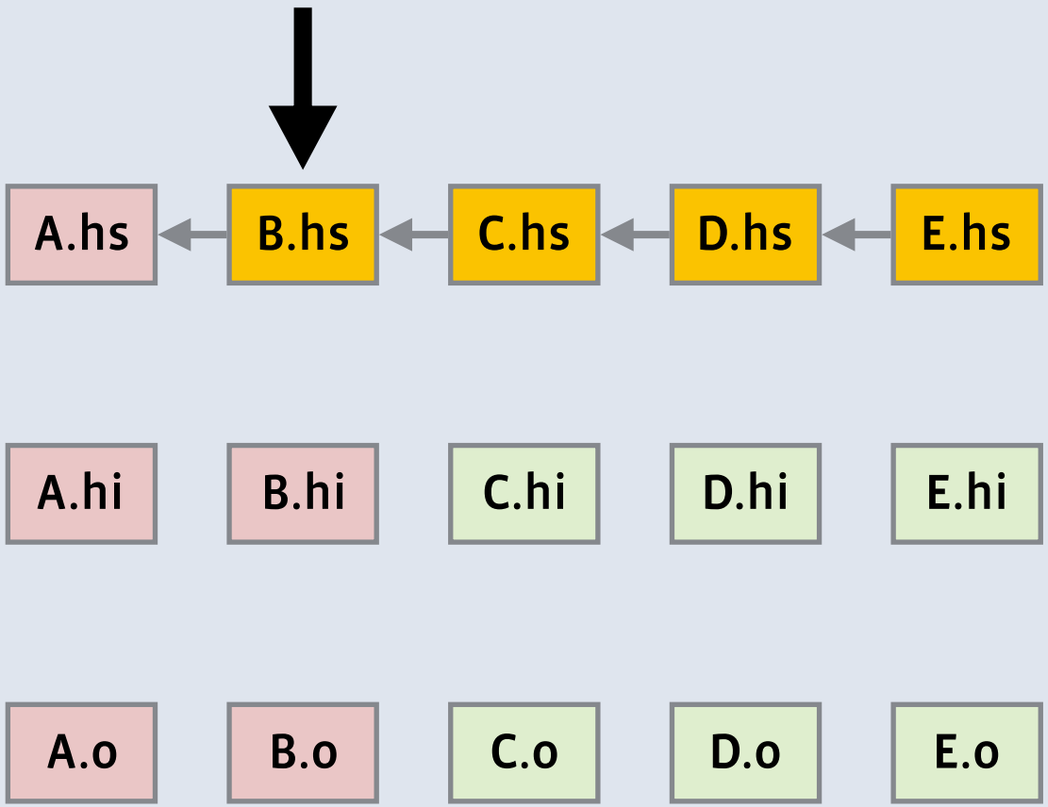

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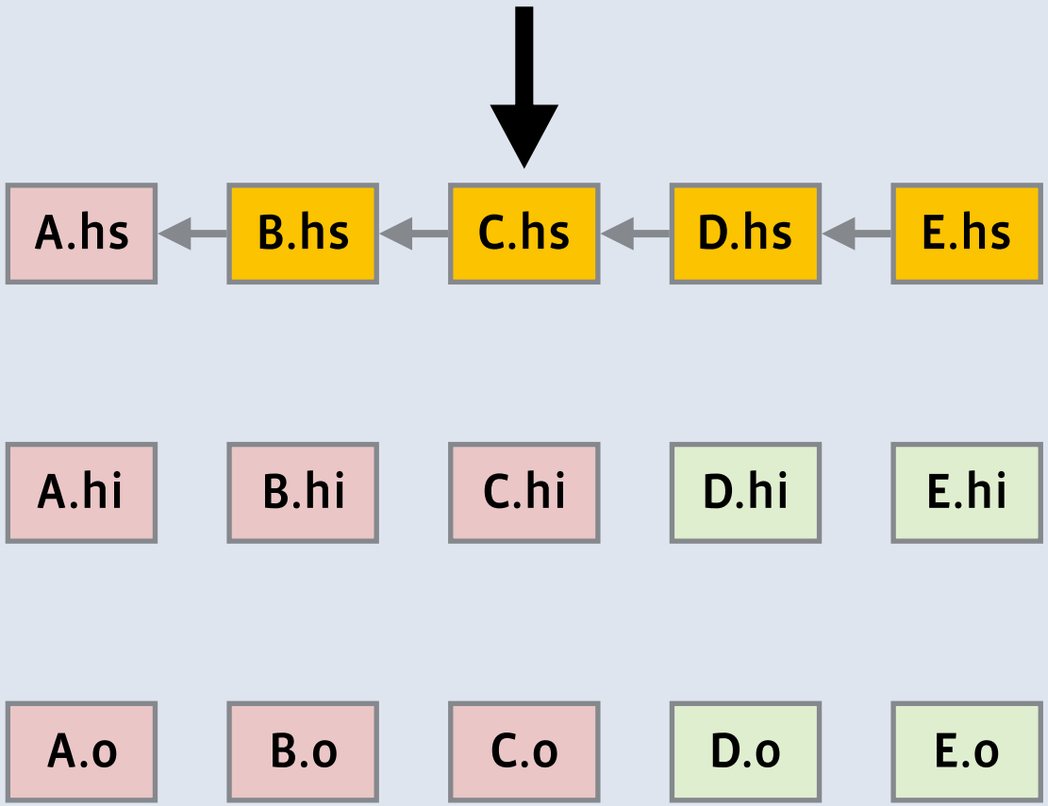

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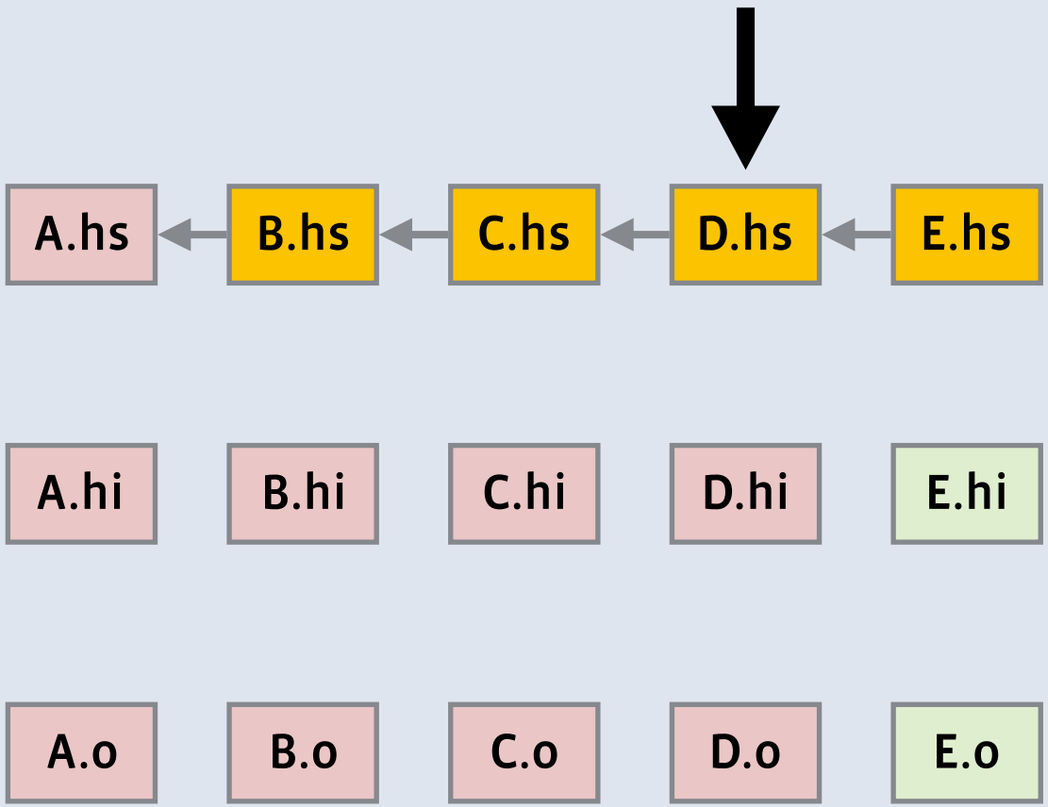

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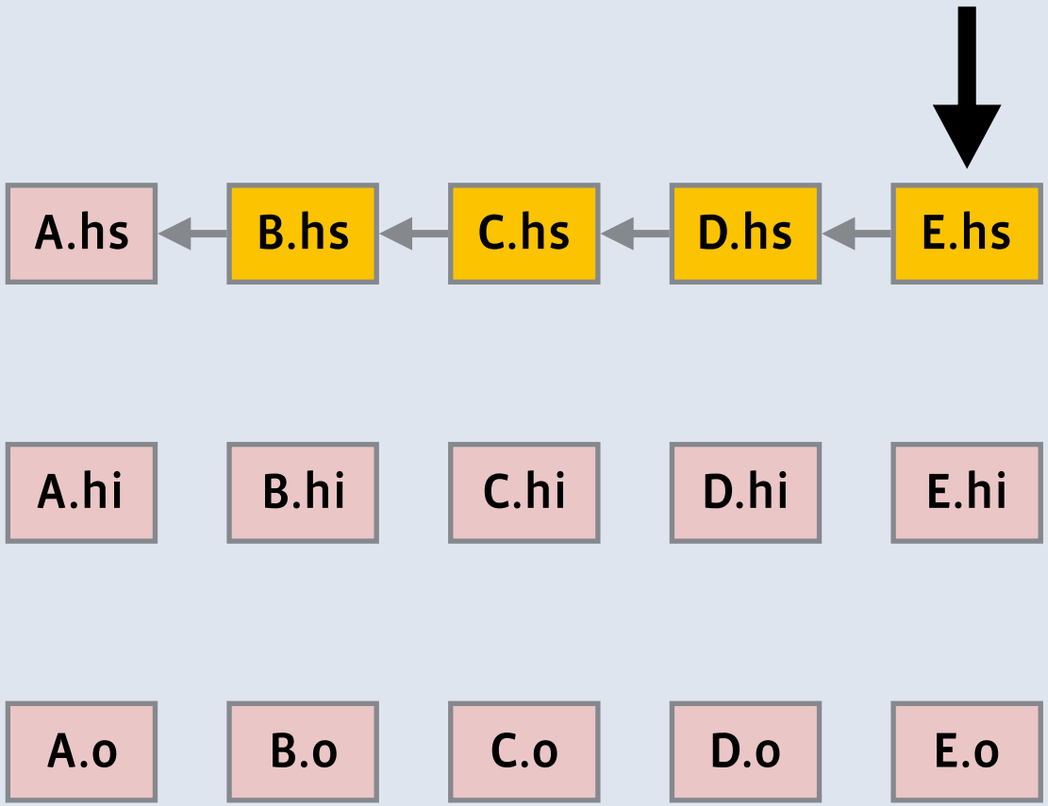


Other

- Binary distributions (Debian, Nix) can recompile GHC without recompiling the world
- hot-swapping
- bit-for-bit determinism

What makes it non-deterministic?

Determinism

- #4012 opened 24 Apr 2010
  - > 200 comments
  - “Are all tickets matching the regex #[4012]+ related” — Joachim Breitner

Uniques

```
type Unique = Int
data Var = Var String Unique

instance Eq Var where
  (Var _ u1) == (Var _ u2) = u1 == u2

instance Ord Var where
  (Var _ u1) `compare` (Var _ u2) = u1 `compare` u2

-- Useful optimization
  -- Fast maps, sets, substitutions…
```

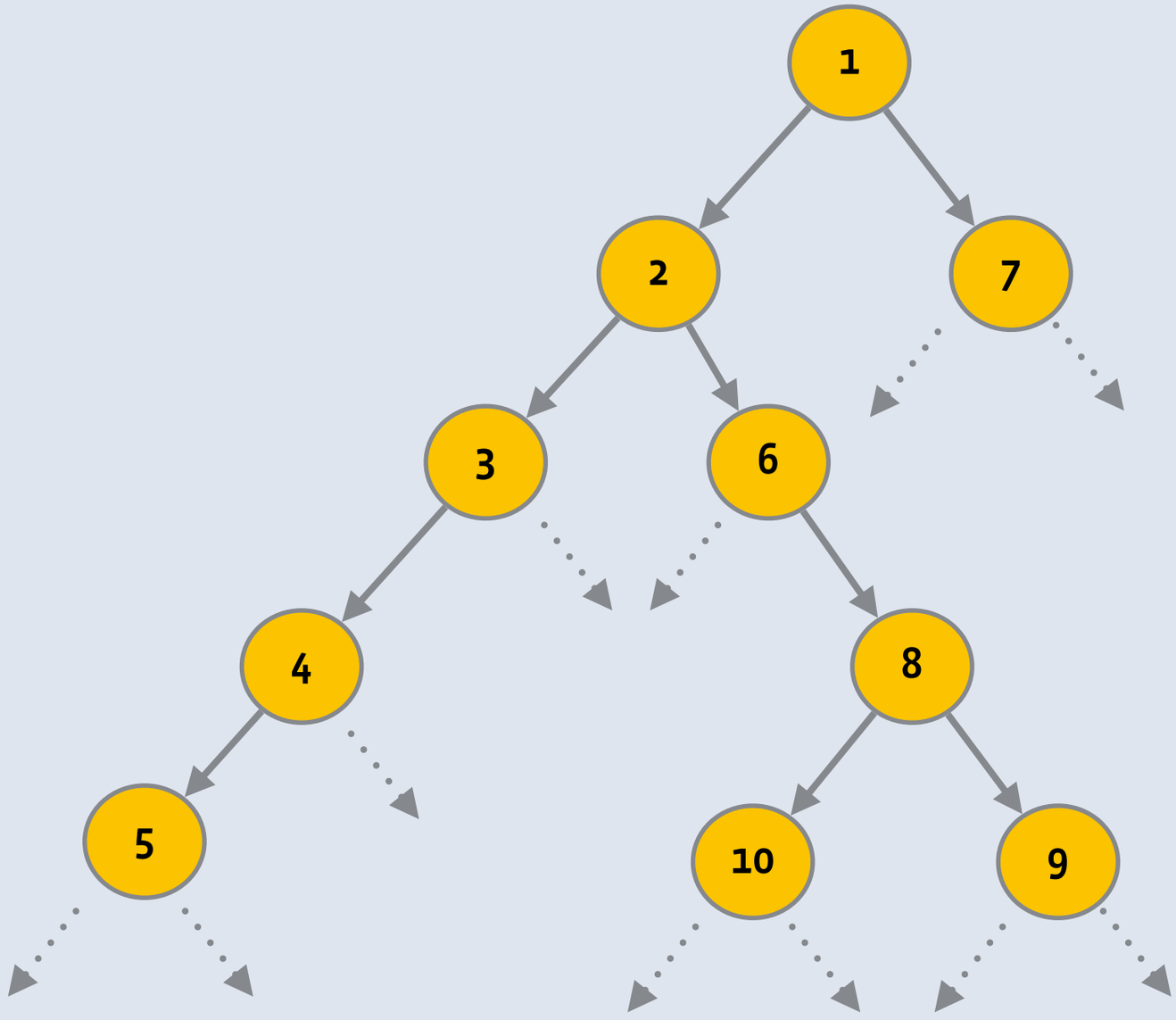
Uniques, how do I get one?

```
data UniqSupply =
  MkSplitUniqSupply Int UniqSupply UniqSupply

-- Lazily generated tree with each node incrementing a
global counter when forced.
-- Really just a nice way of pulling it out of IO.

takeUniqFromSupply :: UniqSupply -> (Unique,
UniqSupply)
takeUniqFromSupply (MkSplitUniqSupply v us _) = (v,
us)
```

UniqSupply



Uniques

- To get determinism, either:
  - stable across compilations
  - not affecting the ABI

Option 1: stable Uniques

Unique nondeterminism

- Global UniqueSupply

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- Need to allocate Uniques when type-checking interface files
- Type checking interface files is lazy
  - The interface file for the file currently being compiled may or may not exist
    - ghc --make: any subset of interface files
- we want to parallelize with multiple threads
- and still get the same Uniques!

Option 2: ABI doesn't depend on Uniques

Nondeterministic uniques

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showSquared a = show (a * a)
-- What's the inferred type?
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They are operationally different!

Nondeterministic uniques, why?

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The fix

- No easy fix
  - >100 commits

Other examples

- SCCs
- Free variables
  - let floating
  - worker-wrapper
    - Arrow, ApplicativeDo, RecursiveDo desugaring
- Anchoring of instances, rules and type families
- Order of record fields
- …

How do we keep it fixed?

The long-term fix

- Combination of types and convention

The long-term fix

- Types

```
216 instance Ord Unique where
217     a  < b = ltUnique a b
218     a <= b = leUnique a b
219     a  > b = not (leUnique a b)
220     a >= b = not (ltUnique a b)
221     compare a b = nonDetCmpUnique a b
222
```

```
112 foldUniqSet = foldUFM
```

```
80 nameSetElems     = uniqSetToList
```

```
89 nameSetAny :: (Name -> Bool) -> NameSet -> Bool
90 nameSetAny = uniqSetAny
91
92 nameSetAll :: (Name -> Bool) -> NameSet -> Bool
93 nameSetAll = uniqSetAll
94
```

The long-term fix

- Convention

```
1233  zonkTyCoVarsAndFV :: TyCoVarSet -> TcM TyCoVarSet
1234  zonkTyCoVarsAndFV tycovars =
1235    tyCoVarsOfTypes <$> mapM zonkTyCoVar (nonDetEltsUFM tycovars)
1236    -- It's OK to use nonDetEltsUFM here because we immediately forget about
1237    -- the ordering by turning it into a nondeterministic set and the order
1238    -- of zonking doesn't matter for determinism.
```

The long-term fix

- If all else fails, test suite
- Testing
  - -dunique-increment=-1
  - that's all the regression tests
- Mind-map almost done

What's coming to GHC 8.0.2?

GHC 8.0.2

- Observable determinism
  - GHC
  - stackage - 1200 packages
- Open a Trac ticket!
  - DIY non-determinism in TH

Thanks

- Simon Marlow
- Simon Peyton Jones
- Gemma Silvers
- Jon Coens
- Ben Gamari
- Thomas Miedema
- Herbert Valerio Riedel

Questions?

Other examples

- Uniques in error messages for unreachable code
- Uniques used to get a unique name for automatic deriving
- Nondeterministically abstracted RULES for specialization
- Unique order leaking to TemplateHaskell
- …