Gneiss
A nice component framework in SPARK

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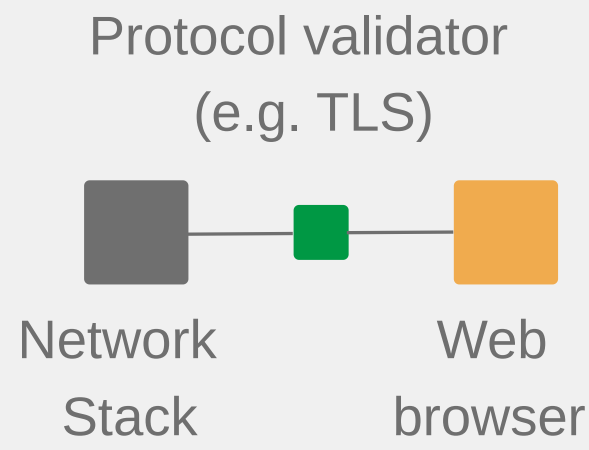
Trusted Components

- Can’t reimplement everything
- **Solution: software reuse**
  - Untrusted software (gray)
  - Policy object (green)
  - Client software (orange)
- **Policy and proxy components**
  - Formally verified
  - Limited complexity



Ensuring Correctness
Prerequisites

- **Correctness by proof**
  - Absence of runtime errors
  - Functional correctness
- **Tools**
  - Formalization language
  - Mapping between implementation and proof

- **Reusability**
  - Proofs require effort
  - Abstraction from actual platform
- **Provability**
  - Formal specification
  - Manageable complexity
  - Deterministic behaviour

Correctness by Proof and Tools

SPARK

- **Programming Language**
  - Based on Ada
  - Compilable with GCC and LLVM
  - Customizable runtime
  - Contracts (preconditions, postconditions, invariants)
- **Verification Toolset**
  - Absence of runtime errors
  - Functional correctness

```
function Abs (I : Integer)
   return Integer
with
   Pre  => I > Integer'First,
   Post => Abs'Result >= 0;


procedure Inc
   (I : in out Integer)
with
   Pre    => I < Integer'Last,
   Post   => I = I'Old + 1,
   Global => null;
```

Provability and Reusability
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- **Reusability**
  - Platform abstraction
  - Interface mappable to multiple different semantics
  - Only dependencies satisfiable by all platforms

- **Provability**
  - Platform formalization
  - Assumptions coarse enough to be valid on multiple platforms
  - Assumptions strong enough to ease proving

Example: Block Client

Block Devices
Client Interface

- **Block device**
  - Storage device of equally sized blocks
  - Block size is typically 512 or 4096 bytes
- **Packet descriptor**
  - Starting block number
  - Amount of blocks
  - Read/Write/Sync/Trim
  - Memory location

- Create packet descriptor
- Allocate memory for request
- (write data)
- Send request to block device
- Receive answer from block device
- (read data)

Gneiss Block Client
Formalizing properties

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- **Formalize properties of platform API**
  - Packet object is needed
  - Packet object can always be initialized
  - Request memory must be allocated separately
  - Memory allocation might fail
  - Submitting must be checked
  - Submitting works always if ready

```
packet = Packet_descriptor(
           WRITE, start, count);
try {
    packet.alloc_packet(
        block_size * count);
    if(ready_to_submit()){
        submit(packet);
}
catch (Alloc_Error) { }
```

Gneiss Block Client
Formalizing properties

- **Define packet type**
  - No exceptions, allocation success is a property
- **Define precondition from formalized properties**
  - Packet must be allocated
  - And the platform must be ready

```
type Packet is record
   Start     : Natural;
   Length    : Positive;
   Op        : Operation;
   Allocated : Boolean;
end record;

function Ready return Boolean;

procedure Submit (P : Packet)
with
  Pre => P.Allocated
         and then Ready;
```

Gneiss Block Client
Formalizing properties

- **Packet properties can be changed by the programmer**
  - Allocation status can be set without actually successfully allocating
  - Packet can be submitted multiple times
- **`Submit` does not change the platform state**
  - Calling **`Submit`** should invalidate **`Ready`**

```
P := Packet'(Start     => 0,
             Length    => 1,
             Op        => READ,
             Allocated => True);
if P.Allocated and then Ready
then
   Submit (P);
   Submit (P);
end if;
```

Gneiss Block Client
Formalizing properties

- **Use state enum instead of boolean**
- **Encapsulate Packet type**
  - Can only be changed by platform calls
  - Can only be created in state **`Empty`**
  - Cannot be copied (**`limited`**)

```
type Packet is limited private;

type Packet_State is
  (Empty, Allocated);

function Create
   (Start  : Natural;
    Length : Positive;
    Op     : Operation)
   return Packet
with
  Post => State (Create'Result) =
                Empty;

function State (P : Packet)
   return Packet_State;
```

Gneiss Block Client
Formalizing properties

- **Submit changes packet state**
- **Submit changes platform state**
  - **Ready** depends on platform state
  - Once **Submit** is called, **Ready** must be checked again

```
function Ready return Boolean
with
  Global => (Input => Platform);
procedure Submit
   (P : in out Packet)
with
  Pre    => State (P) = Allocated
            and then Ready,
  Post   => State (P) = Empty,
  Global => (In_Out => Platform);
```

Gneiss Block Client
A Second Platform

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- **`write` might fail**
  - ENOSYS (not implemented)
  - EINVAL (wrong argument)
  - EFBIG (offset out of file)
  - EBADF (bad file descriptor)
  - **EAGAIN (out of resources)**
- **No way to make sure it succeeds, `submit` must be able to fail, too**

```
struct block_packet packet =
    {0, 1, WRITE, 0};
int result;

packet.ptr = malloc
    (block_size * packet.len);

if(packet.ptr){
   result = write(fd, &packet);
}
```

Gneiss Block Client
A Second Platform

- **Submit** must be able to fail
  - It might change the packet state or leave it as is
  - An unsuccessfully submitted packet can be submitted again

```
procedure Submit
   (P : in out Packet)
with
  Pre    =>
    State (P) = Allocated,
  Post   =>
    State (P) in
      Empty | Allocated,
  Global => (In_Out => Platform);
```

Gneiss Block Client
Adapting the first platform

- Both platforms have different semantics
- The second platform cannot be expressed with the first one
- But the first one can be expressed with the second one

```
procedure Submit
   (P : in out Packet)
is
begin
   if Ready then
      Submit_Native (P);
   end if;
end Submit;
```

Gneiss
Summary

- Asynchronous, event based
- Supports capabilities
- Callbacks via generics
- Limited dynamic resource allocation
  - Platform dependent
- No memory pressure
- No aliasing

- **Multiple platforms**
  - Genode
  - Linux
  - Muen
- **Interfaces**
  - Log client/server
  - Block client/server
  - Timer client
  - Message client/server
  - Shared memory

Questions?

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