

# **Returning data-flow to asynchronous programming**

**Matt Gilbert, Senior Staff Engineer, Qualcomm Technologies, Inc. 2018-04-16**

# Background

- Hardware design focuses on information flow (data and control): how do you compose the pieces of execution to balance speed, efficiency, and area?
- We self-impose asynchronicity to avoid accidental time travel between hardware timing boundaries.
- HW execution is modeled as concurrent asynchronous events, using publish/subscribe as the fundamental building block of composition (distributed state, à la actors).

# The problem

Applications composed of decoupled components, connected at runtime, lead to a callback nightmare -- e.g. how do you statically follow data-flow through the system?

# Our solution

Use the static information we have to reconstruct the decoupled callgraph.

Publish/subscribe library runtime connections are based on static information:

- Connections are type safe.
- Strong emphasis on connecting events to state transitions means little usage of dynamic string creation.

*Realization: we have enough static information to re-create a version, or multiple versions of the dynamic data-flow.*

# Basics

publish/subscribe communication is connected through a Registrar of connections.

Consumer:

```
1 //      signature      name
2 //      ↓              ↓
3 reg.lookup<void(std::string)>("print channel").hook([] (const std::string &s) {
4     printf("%s", s.c_str());
5 });
```

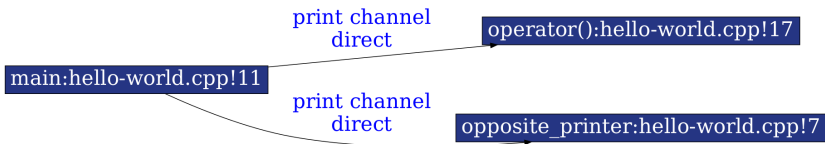
Producer:

```
1 //      signature      name
2 //      ↓              ↓
3 auto print_channel = reg.lookup<void(std::string)>("print channel");
4 // deliver message now
5 print_channel("hello, world\n");
6 // deliver message in 1 cycle
7 //      ↓
8 sched(1, print_channel, "hello, world\n");
```

# Example

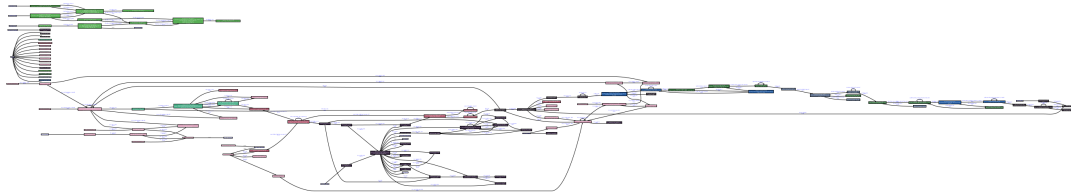
```
1 void opposite_printer(const std::string &s) {
2     std::cout << (s == "hello" ? "world" : "hello") << '\n';
3 }
4
5 int main() {
6     conduit::Registrar reg("reg");
7
8     // producer
9     auto print_channel = reg.lookup<void(std::string)>("print channel", "print_channel producer");
10
11    // first consumer
12    print_channel.hook([] (const std::string &s) {
13        std::cout << s << '\n';
14    });
15
16    // second consumer
17    print_channel.hook(opposite_printer);
18
19    print_channel("hello");
20 }
```

# Reconstructing the decoupled call-graph



```
print_channel producer -> reg.print channel(hello)
hello
world
```

# Real example





# Information recognized by the static analyzer

## Idioms:

- Synchronous and asynchronous connections between components.
- Concurrent state collection (events may happen 0 to N times).
- Channel merge (wait for N different events before triggering).
- Comment processing to allow better semantic descriptions of execution elements.

## State information:

- Non-const data members used in hook call-tree.

# Benefits

- Provides programmers another level of abstraction with which to describe the problem.
  - This is now part of our "modelers contract": descriptive problem decomposition must be reflected through the static analysis (used to bridge the gap between software model and HW implementer).
- Reinforces event  $\rightarrow$  state relationship.
- Helps identify concurrent data races.

# Conclusion

Static analysis combined with programming convention allows reconstruction of data-flow across asynchronous boundaries.



# Thank you

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