Using LLVM in the presence of timing constraints

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LLVM European Developers Meeting

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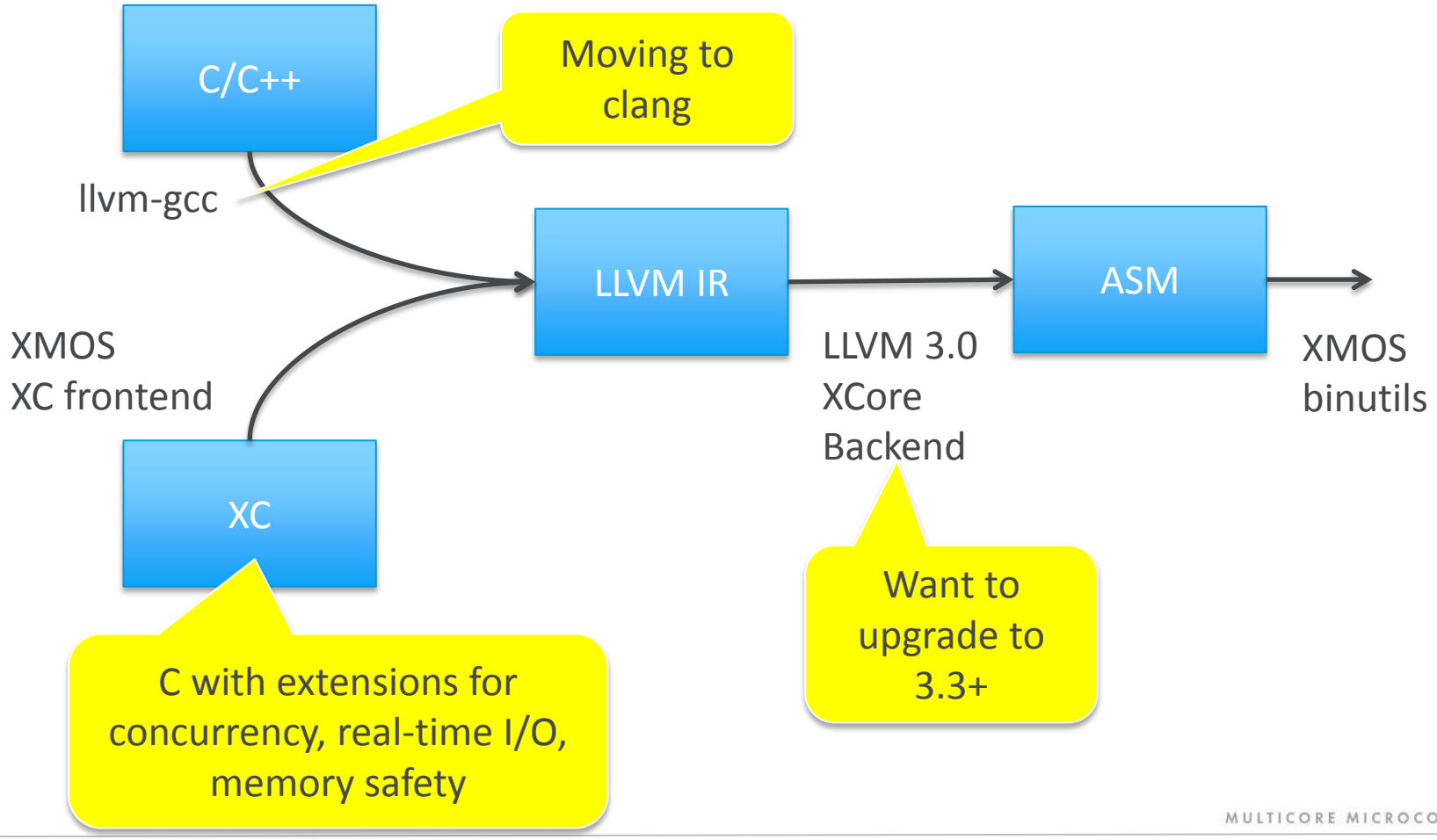
XMOS and LLVM

- XMOS uses LLVM to implement C + XC compilers:



Real-time WCET constraints

- Code for our devices is hard real-time

```
port p, q;
time_t t1, t2;
…
wait_for_edge_and_timestamp(p, &t1);
…
while (!cond) {
  …
  output_signal_and_timestamp(q, &t2);
  timing_assert((t2 - t1) < 270);
  …
  wait_for_edge_and_timestamp(p, &t1);
}
```

If the time between these points is less that 270ns then the program does not work

- We have an analysis tool to check these constraints (XTA)

What's the problem?

- LLVM has many optimizations
- In general, these optimization aim to improve average execution time not worst case execution time
- In general, these optimization aim to make the whole function (or perhaps loop within the function) faster - no prioritization between execution paths
- Optimizations can make things much worse (from a WCET perspective)

Example: Scheduling

- Scheduling can mess things up:

```
port p, q;
time_t t1, t2;
…
wait_for_edge_and_timestamp(p, &t1);
…
while (!cond) {
  [code sequence 1]

  output_signal_and_timestamp(q, &t2);
  timing_assert((t2 - t1) < 270);
  [code sequence 2]
  [code sequence 3]
  wait_for_edge_and_timestamp(p, &t1);
}
```

Constraints are met.
The program works!

Example: Scheduling

- Scheduling can mess things up:

```
port p, q;
time_t t1, t2;
…
wait_for_edge_and_timestamp(p, &t1);
…
while (!cond) {
  [code sequence 1]
  [code sequence 2]
  output_signal_and_timestamp(q, &t2);
  timing_assert((t2 - t1) < 270);

  [code sequence 3]
  wait_for_edge_and_timestamp(p, &t1);
}
```

Takes too long. Broken!

Example: Invariant hoisting

- Loop invariant hoisting can mess things up:

```
port p, q;
time_t t1, t2;
…
wait_for_edge_and_timestamp(p, &t1);
…

while (!cond) {
  [code sequence 1]
  output_signal_and_timestamp(q, &t2);
  timing_assert((t2 - t1) < 270);
  [code sequence 2]
  [code sequence 3]
  wait_for_edge_and_timestamp(p, &t1);
}
```

Constraints are met.
The program works!

Example: Invariant hoisting

- Loop invariant hoiscan mess things up:

```
port p, q;
time_t t1, t2;
…
wait_for_edge_and_timestamp(p, &t1);
…
[code sequence 2]
while (!cond) {
  [code sequence 1]
  output_signal_and_timestamp(q, &t2);
  timing_assert((t2 - t1) < 270);

  [code sequence 3]
  wait_for_edge_and_timestamp(p, &t1);
}
```

Takes too long. Broken!

What are we going to do?

- What are we going to do….
- Um…

Some hopes

- Most optimizations are OK
- We can sort most of this out in the scheduler
- … but that requires a scheduler that isn't just a basic block scheduler
- Need to avoid a big fork. Most platforms/code do not care about this as much so cannot rewrite LLVM to be "worst case constraint aware" everywhere.
- Limiting optimizations that cause problems is hopefully a matter of tuning rather than rewriting