EENG 426/CPSC 459/ENAS 876
Silicon Compilation

Handshaking expansions

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Handshaking expansions

CHP: high level constructs such as send and receive

$*[\ L?x;\ \ R!x\ ]$

Production rules: circuit description

$$a \wedge b \mapsto c{\downarrow}$$
$$\neg a \vee \neg b \mapsto c{\uparrow}$$

Handshaking expansions: intermediate form

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Handshaking expansions

Handshaking expansions are CHP programs, with the following restrictions:

- only Boolean-valued variables
- no communication actions
- only constants on the RHS of assignments

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Handshaking expansions

Replace

$x := y$

with

$[y \longrightarrow x{\uparrow}\ [\!]\ \neg y \longrightarrow x{\downarrow}]$

Variables of a process are classified into:

- internal (local variables, not shared)
- input (shared, only read by the process)
- output (shared, written by the process)

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Handshake protocols

We first consider the case when we have bare communication actions (no data being sent/received).

Synchronization is implemented by using two wires.

Two-phase handshake: (initially all variables are false)

$X: \quad xo\uparrow; [xi]$
$Y: \quad [yi]; yo\uparrow$

X: *active* communication protocol
Y: *passive* communication protocol

$xo = yi; yo = xi$

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Handshake protocols

If all variables are true initially:

$X: \quad xo\downarrow; [\neg xi]$
$Y: \quad [\neg yi]; yo\downarrow$

Both protocols synchronize the two actions.

Since the final state of one implementation is the initial state of the other, we can *alternate* the two implementations.

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Handshake protocols

Problem: it is not always possible to alternate the two implementations.

$[B \longrightarrow X$
$[\!]\neg B \longrightarrow$ **skip**
$]$

General solution: use the *same* implementation for the two.

(Two-phase handshake protocol)

$X: \quad xo := \neg xo; [xi = xo]$
$Y: \quad [yi \neq yo]; yo := \neg yo$

This implementation is costly.

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Handshake protocols

Four-phase handshaking:

$X: \quad xo\uparrow; [xi]; xo\downarrow; [\neg xi]$
$Y: \quad [yi]; yo\uparrow; [\neg yi]; yo\downarrow$

X: *active* communication protocol
Y: *passive* communication protocol

The waits are simplfied, which results in better circuits.

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Handshaking expansions

Example:

$$*[L;\ R]$$

becomes:

$$*[[li];\ lo\uparrow;\ [\neg li];\ lo\downarrow;\ ro\uparrow;\ [ri];\ ro\downarrow;\ [\neg ri]]$$

or:

$$*[lo\uparrow;\ [li];\ lo\downarrow;\ [\neg li];\ [ri];\ ro\uparrow;\ [\neg ri];\ ro\downarrow]$$

or:

$$*[[li];\ lo\uparrow;\ ro\uparrow;\ [ri];\ [\neg li];\ lo\downarrow;\ ro\downarrow;\ [\neg ri]]$$

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Implementing probes

Example:

$$*[[\overline{C} \longrightarrow x\uparrow;\ C\ \ [\!]\ \overline{D} \longrightarrow x\downarrow;\ D\ ]]$$

becomes:

$$*[[ci \longrightarrow x\uparrow;\ \underbrace{[ci]}_{omit};\ co\uparrow;\ [\neg ci];\ co\downarrow$$
$$[\!]\ di \longrightarrow x\downarrow;\ \overbrace{[di]};\ do\uparrow;\ [\neg di];\ do\downarrow$$
$$]]$$

or:

$$*[[ci \longrightarrow x\uparrow;\ co\uparrow;\ [\neg ci];\ co\downarrow$$
$$[\!]\ di \longrightarrow x\downarrow;\ do\uparrow;\ [\neg di];\ do\downarrow$$
$$]]$$

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Implementing probes

Example:

$$*[[\overline{L} \longrightarrow R;\ L]]$$

becomes:

$$*[[li \longrightarrow ro\uparrow;\ [ri];\ ro\downarrow;\ [\neg ri];\ lo\uparrow;\ [\neg li];\ lo\downarrow]]$$

If port X is probed, we implement it using a passive communication protocol.

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Reshuffling

Since the first part of the four-phase protocol synchronizes the two actions, we can postpone the last part of the protocol.

- This transformation is called **reshuffling**
- Reshuffling changes the order in which signals change
  $\Rightarrow$ different circuit!
- Circuit efficiency can be significantly altered

Reshuffle with care: you might introduce deadlock!

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Lazy-active handshake protocol

Lazy-active protocol:

$X : \quad [\neg xi] ; xo\uparrow ; [xi] ; xo\downarrow$

The wait for xi to be **false** can always be postponed until the next time the handshake protocol is executed.

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Analysis of reshuffling

We can analyze the effect of a reshuffling at the CHP level of abstraction!

A 4-phase handshake is two 2-phase handshakes—i.e., two synchronizations.

- Write all handshaking using 2-phase CHP: only two-phase handshakes allowed. $L_{4\phi} \triangleright L^+_{2\phi} ; L^-_{2\phi}$
- Relation between two 2-phase handshakes L and R?
  - Test against two environments: $L; R$ and $R; L$!
  - If both work, then parallel
  - If only one works, in sequences
  - If neither work, then "$\star$"

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Analysis of reshuffling

Passive, passive:

$[li] ; lo\uparrow ; [ri] ; ro\uparrow \quad \triangleright \quad L^+ ; R^+$

$[li \wedge ri] ; lo\uparrow , ro\uparrow \quad \triangleright \quad L^+ \star R^+$

$[ri] ; ro\uparrow ; [li] ; lo\uparrow \quad \triangleright \quad R^+ ; L^+$

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Analysis of reshuffling

Active, active:

$lo\uparrow ; [li] ; ro\uparrow ; [ri] \quad \triangleright \quad L^+ ; R^+$

$lo\uparrow , ro\uparrow ; [li \wedge ri] \quad \triangleright \quad L^+ \| R^+$

$ro\uparrow ; [ri] ; lo\uparrow ; [li] \quad \triangleright \quad R^+ ; L^+$

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Analysis of reshuffling

Active, passive:

$lo{\uparrow};\ [li \wedge ri];\ ro{\uparrow}$	$\triangleright$	$L^+;\ R^+$
$lo{\uparrow};\ [ri];\ ro{\uparrow};\ [li]$	$\triangleright$	$L^+ \| R^+$
$[ri];\ lo{\uparrow};\ [li];\ ro{\uparrow}$	$\triangleright$	$L^+ \star R^+$
$[ri];\ ro{\uparrow},\ lo{\uparrow};\ [li]$	$\triangleright$	$R^+;\ L^+$

Reshuffling examples

$*[\,[li];\ ro{\uparrow};\ [ri];\ ro{\downarrow};\ [\neg ri];\ lo{\uparrow};\ [\neg li];\ lo{\downarrow}]$

$\triangleright$

$*[L^+ \star (R^+;\ R^-);\ L^-\ ]$

$*[\,[li];\ ro{\uparrow};\ [ri];\ lo{\uparrow};\ [\neg li];\ ro{\downarrow};\ [\neg ri];\ lo{\downarrow}]$

$\triangleright$

$*[L^+ \star R^+;\ L^- \star R^-\ ]$

$*[\,[li];\ lo{\uparrow};\ [\neg li];\ lo{\downarrow};\ ro{\uparrow};\ [ri];\ ro{\downarrow};\ [\neg ri]]$

$\triangleright$

$*[L^+;\ L^-;\ R^+;\ R^-\ ]$

Implementing bullets

$L \bullet R \quad \triangleright \quad L^+;\ R^+;\ L^-;\ R^-$

$\qquad\quad\ \triangleright \quad L^+;\ R^+;\ R^-;\ L^-$

Interleave the parts of the handshaking expansion so that neither L nor R can complete unless the other has begun.