

Lazy Execution

- What is it?
- Semantics: the by-need trigger
- Applications:
 - Lazy streams
 - Lazy bounded buffer
 - The Hamming problem

What is lazy execution?

- A statement is only executed when its result is needed somewhere in the program
- We extend the data-driven model to the demand-driven model by the concept of by-need trigger

$\langle s \rangle ::=$	
skip	Empty statement
$\langle s \rangle_1 \langle s \rangle_2$	Statement sequence
local $\langle x \rangle$ in $\langle s \rangle$ end	Variable creation
$\langle x \rangle_1 = \langle x \rangle_2$	Variable-variable binding
$\langle x \rangle = \langle v \rangle$	Value creation
if $\langle x \rangle$ then $\langle s \rangle_1$ else $\langle s \rangle_2$ end	Conditional
case $\langle x \rangle$ of $\langle \text{pattern} \rangle$ then $\langle s \rangle_1$ else $\langle s \rangle_2$ end	Pattern matching
$\{ \langle x \rangle \langle y \rangle_1 \cdots \langle y \rangle_n \}$	Procedure application
thread $\langle s \rangle$ end	Thread creation
$\{ \text{ByNeed } \langle x \rangle \langle y \rangle \}$	Trigger creation

Demand-driven concurrent kernel language

Semantics of the by-need trigger (1)

$\{\text{ByNeed } P \ Y\}$ has the same effect as the statement **thread** $\{P \ Y\}$ **end**, but $\{P \ Y\}$ will be execute only if Y is needed.

- Trigger : activation condition + action (proc)
- By-need trigger:
 - Extend the execution state by adding a trigger store τ . Then: $(\text{MST}, \sigma, \tau)$.
 - 2 ops: trigger creation & trigger activation
 - Precise what we mean by “needing” a var.

Semantics of the by-need trigger (2)

- Trigger creation: $(\{\text{ByNeed } \langle x \rangle \langle y \rangle\}, E)$

if $E(\langle y \rangle)$ is not determined, then add $\text{trig}(x,y)$ to τ

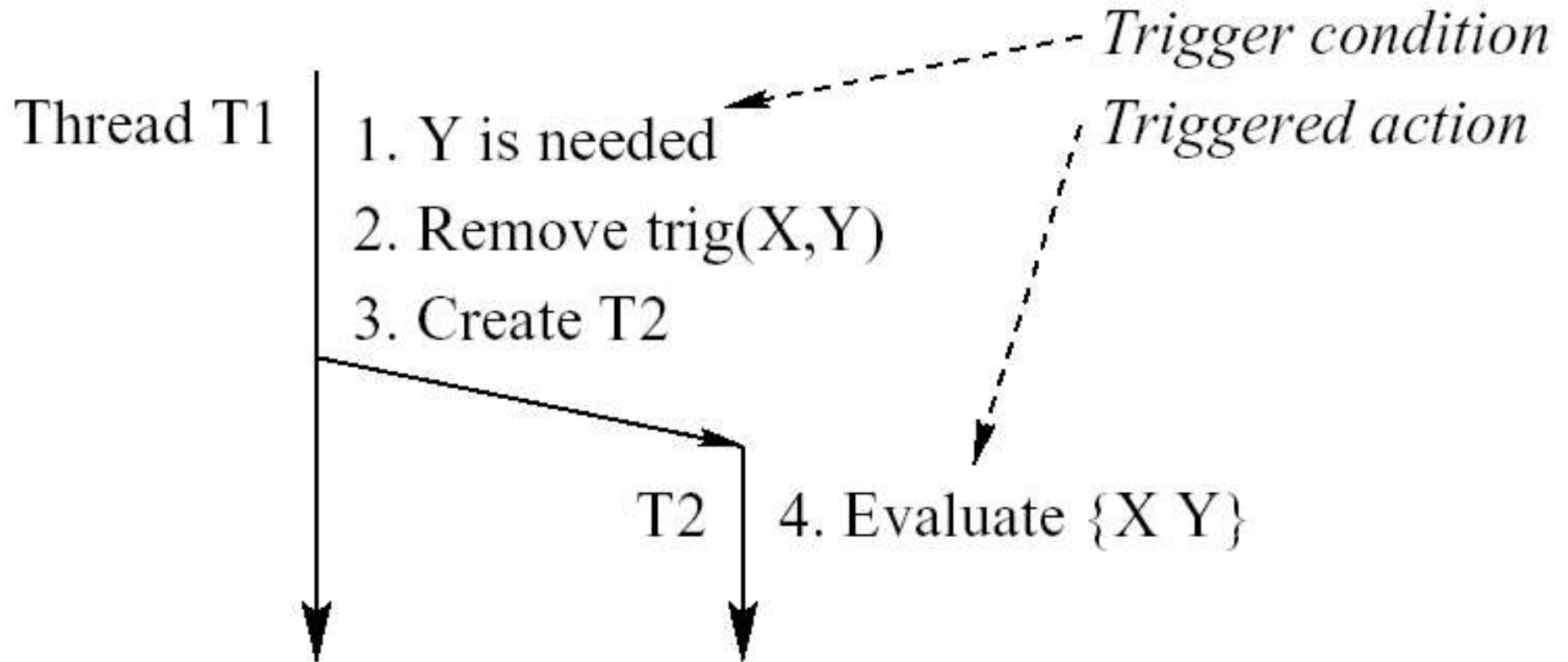
otherwise, create a new thread $(\{\langle x \rangle \langle y \rangle\}, E)$

- Trigger activation:

if Y is needed and τ contains $\text{trig}(x,y)$, then

- remove the trigger from the store
- create a new thread $(\{\langle x \rangle \langle y \rangle\}, E)$

The by-Need Protocol



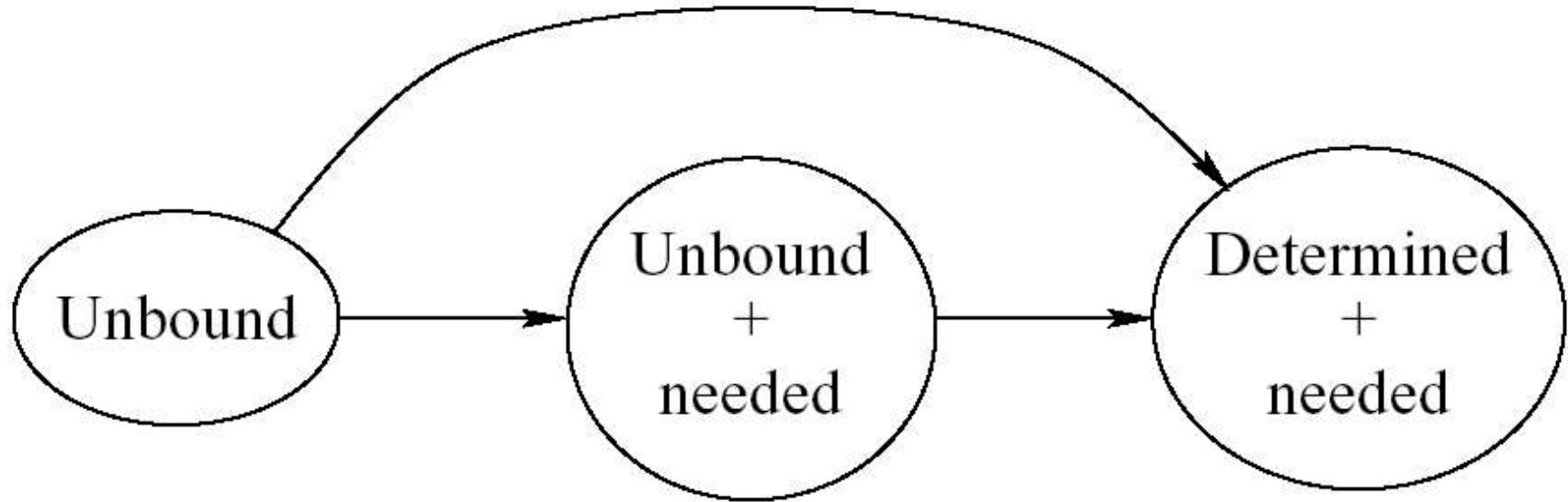
{ByNeed X Y} same effect as **thread** {X Y} **end**

Semantics of the by-need trigger (3)

What does it mean needed ??

- A variable is needed by a suspended operation if the variable must be determined for the operation to continue
- A variable is needed if it is determined

Stages in a variable's lifetime



How to implement lazy functions with
by-need trigger ??

Hamming Problem

Generate the first N integers of the form $2^a 3^b 5^c$ with $a, b, c \geq 0$

