

Lecture ~~21~~²⁰: BPred, OOO

- Today's topics:
 - Branch Predictors
 - Out-of-order execution
- Midterm 2 next Tuesday
 - Same rules as for Midterm 1
 - Notes: bring the sheet from Midterm 1, a new sheet, plus the green sheet
 - Basic calculator, no phones/connectivity
 - Content: starts at slide 7 lecture 8 (numerical reps)
ends at slide 7 lecture 20 (out of order procs)

HW 5-8

Bimodal Predictor



Br at addr 8000

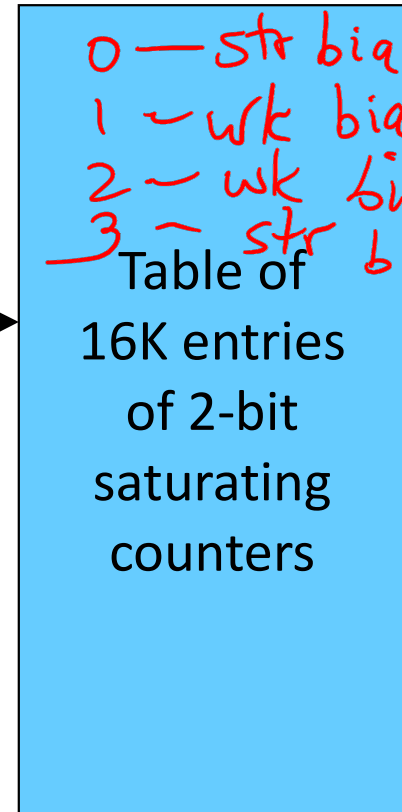
Look up BP
Make a pred
0

0-3

14 bits

Branch PC

8000
32 bit bin num



0 - str bia NT
1 - wk bia NT
2 - wk bia T
3 - str bia T

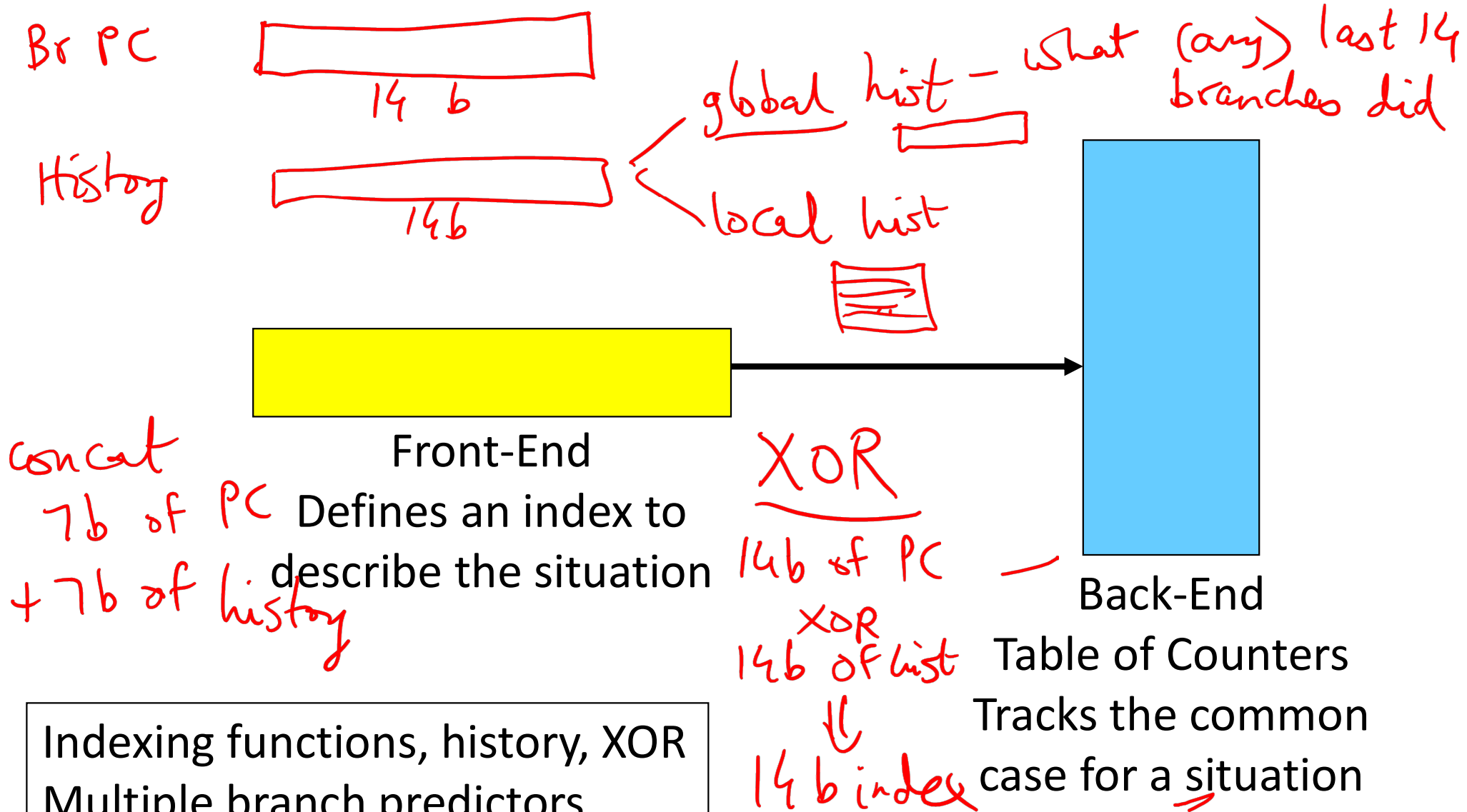
Table of
16K entries
of 2-bit
saturating
counters

14
2 - 1
(16,383)

Outcome is known.
Train BP

Advanced Predictors

$1 \text{ XOR } 0 \Rightarrow 1$
 XOR odd 1's



Indexing functions, history, XOR
 Multiple branch predictors
 Trade-offs

Advanced Predictors

for }

Br Direction Pred
Br Target Pred T/NT
BTB

Tournament Pred

Bimodal

Global

count = 3

Local pred

2

History Register

for i = 0 to 9

BP (Bimodal)
Accuracy = 90%

1 1 1 1 0 1 1 1 1 1 1 1

14b

1 1 1 1 1 1 1 0 1 1 1 1

11
00

Indexing functions, history, XOR

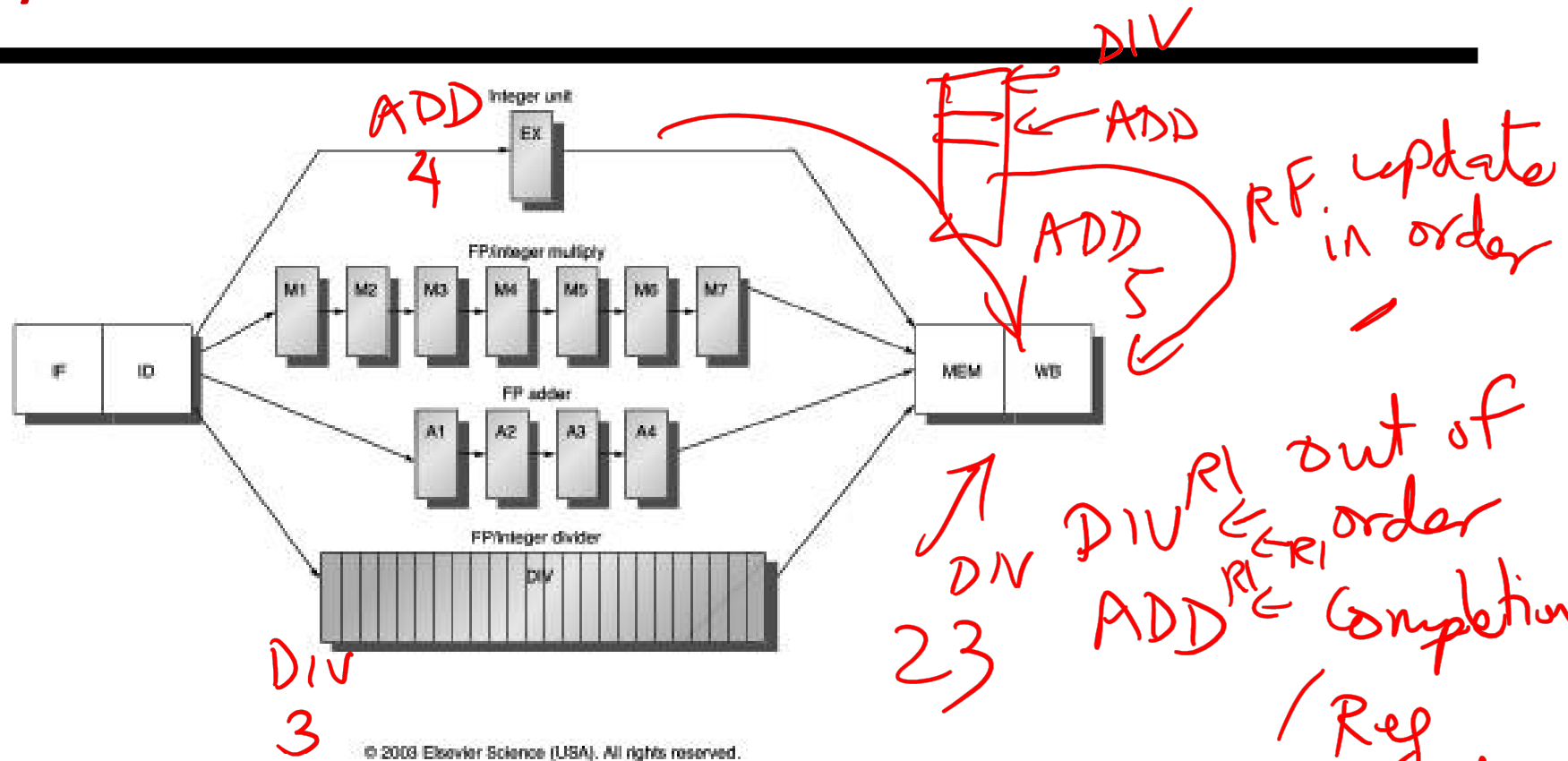
Multiple branch predictors

Trade-offs

context switches

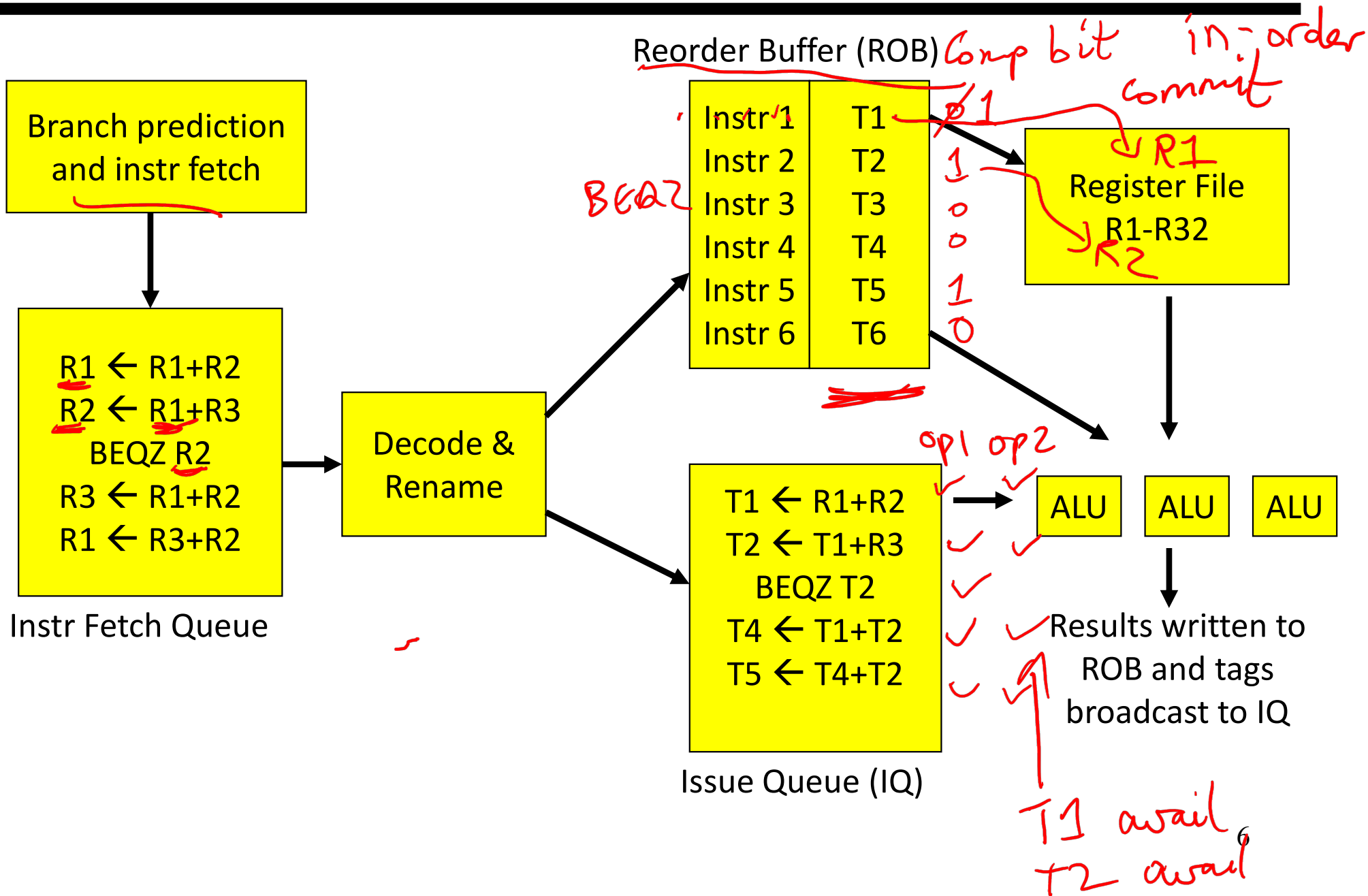
Multicycle Instructions

In-order pipeline

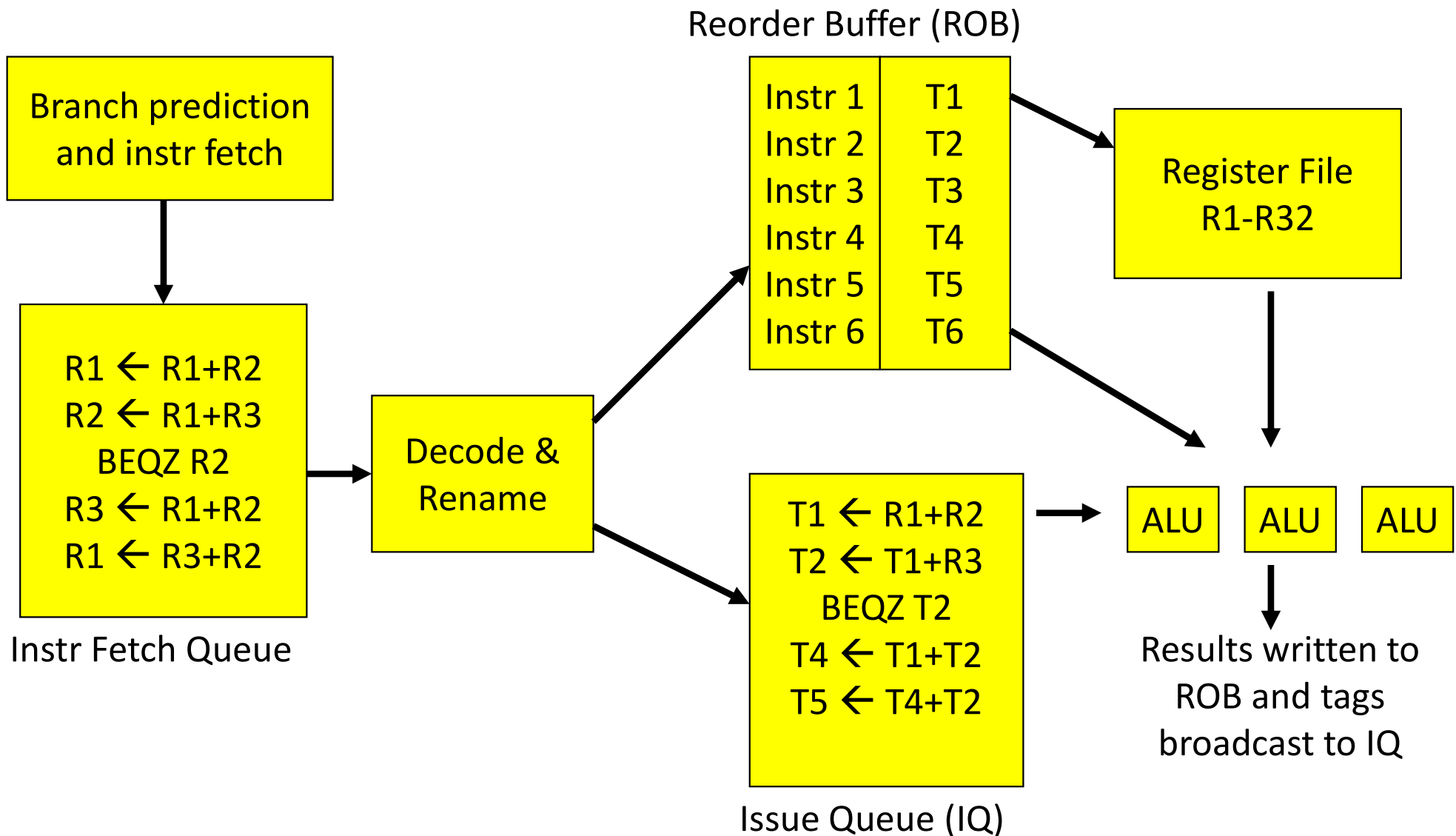


- Multiple parallel pipelines – each pipeline can have a different number of stages
- Instructions can now complete out of order – must make sure that writes to a register happen in the correct order

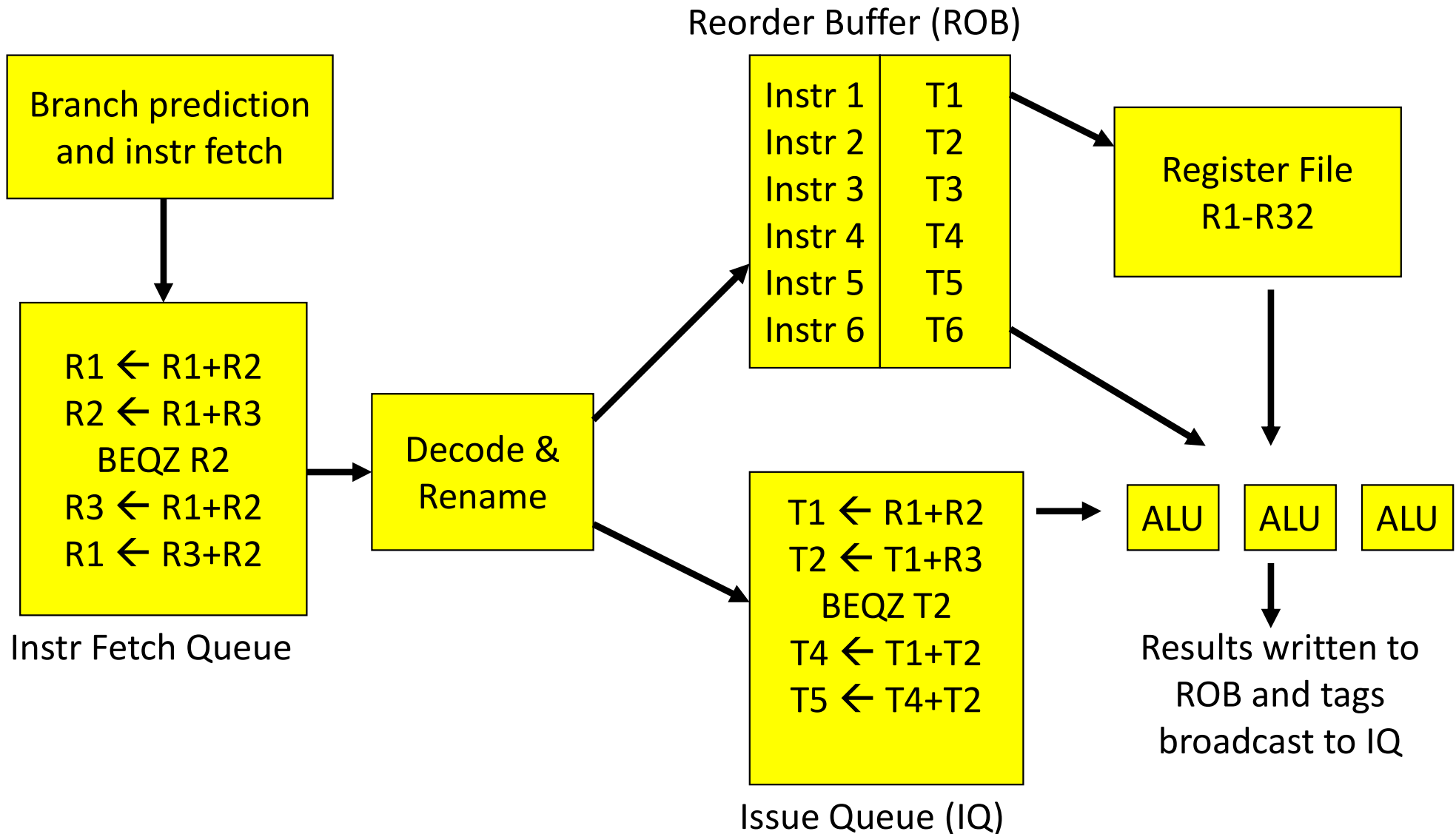
An Out-of-Order Processor Implementation



An Out-of-Order Processor Implementation



An Out-of-Order Processor Implementation



Example Code

Completion times

with in-order

with ooo

ADD R1, R2, R3

5

5

ADD R4, R1, R2

6

6

LW R5, 8(R4)

7

Bubble

7

ADD R7, R6, R5

9

9

ADD R8, R7, R5

10

10

LW R9, 16(R4)

11

Bubble

7

ADD R10, R6, R9

13

9

ADD R11, R10, R9

14

10

$$IPC = \frac{8 \text{ insts}}{10 \text{ cyc}} = 0.8$$

$$IPC = \frac{8 \text{ insts}}{6 \text{ cyc}} = 1.33$$

Memory Hierarchy

- As you go further, capacity and latency increase

