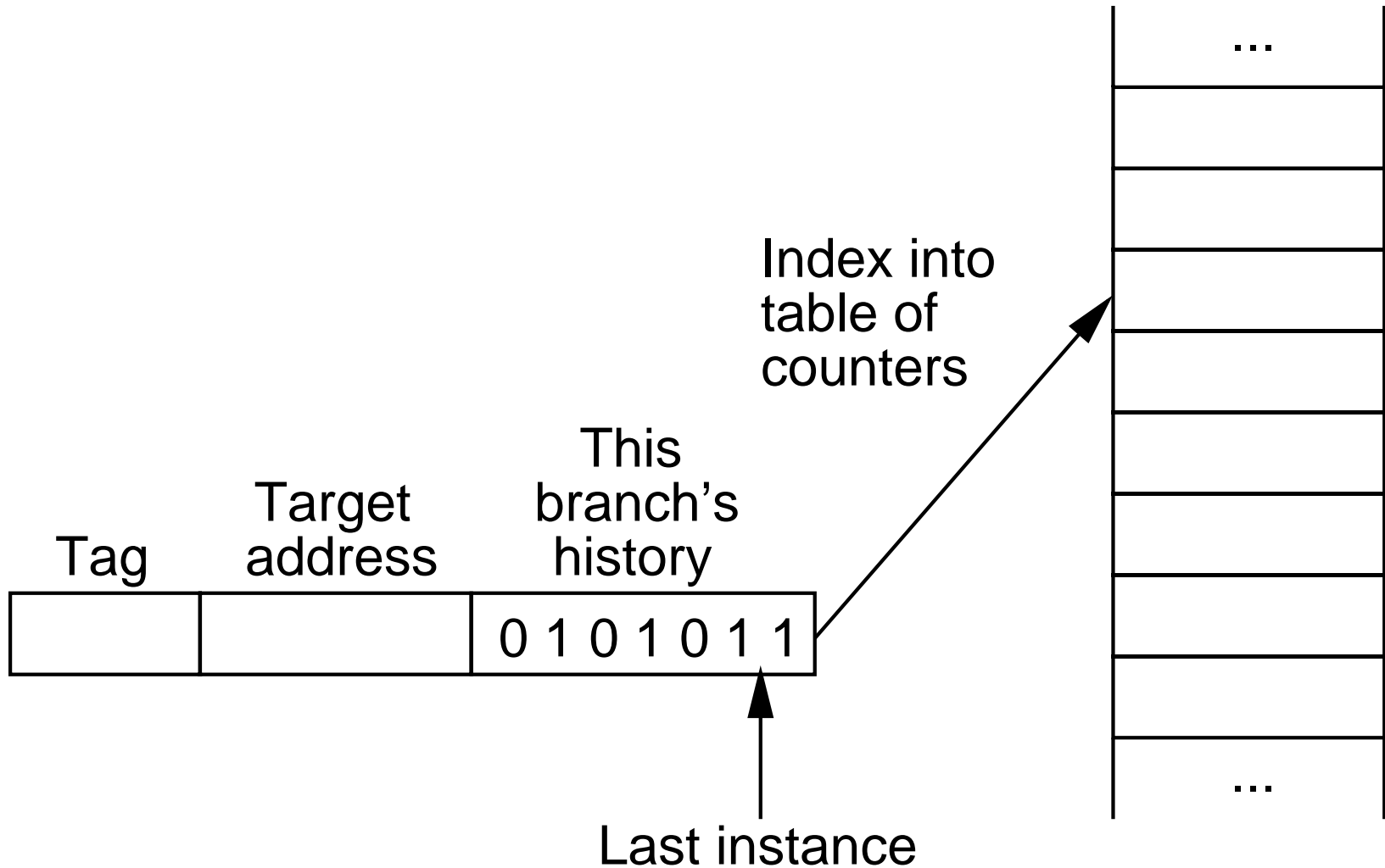
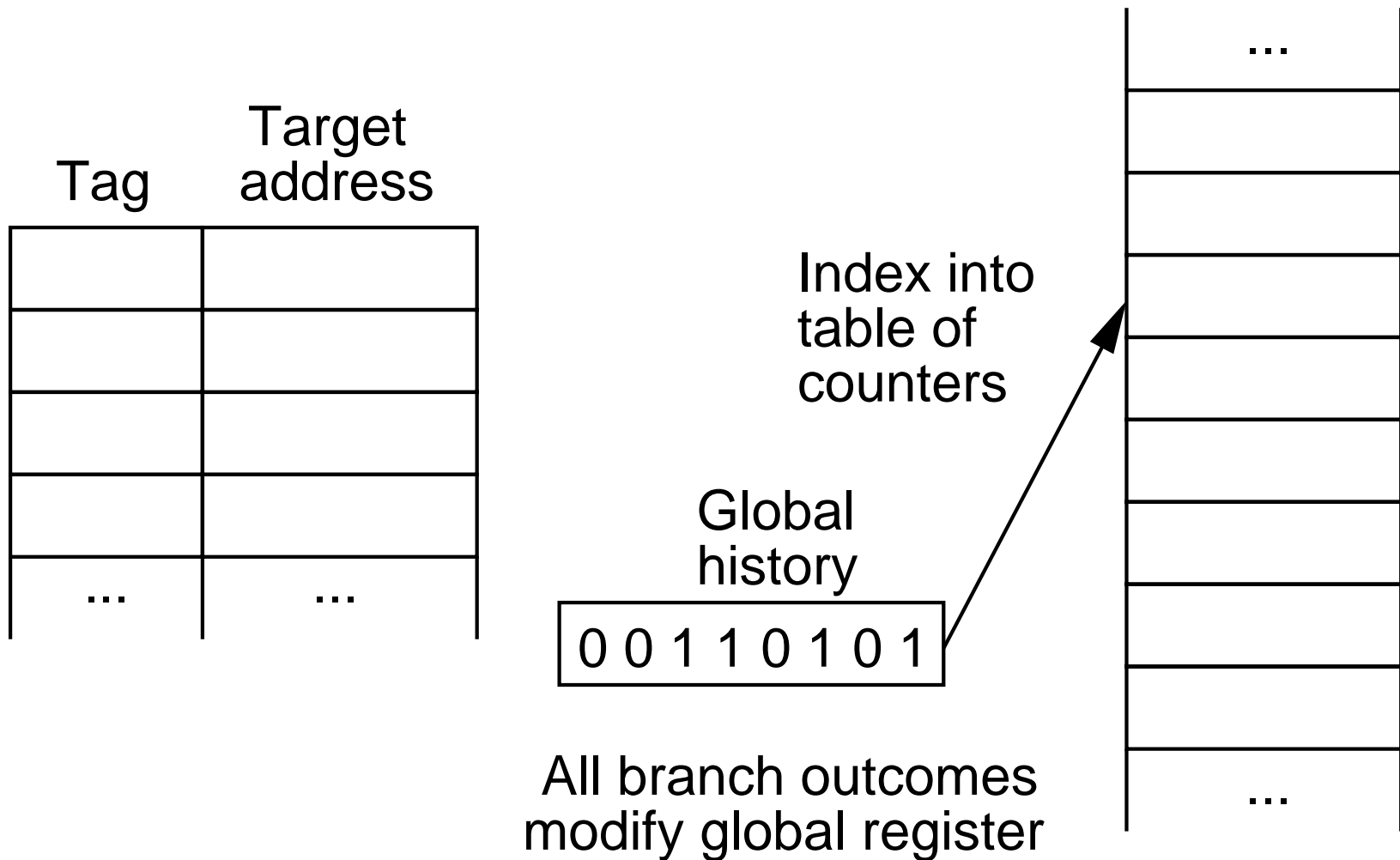
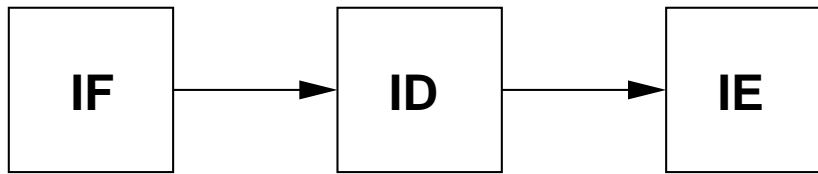


Two-Level BTB Entry with Local History Register



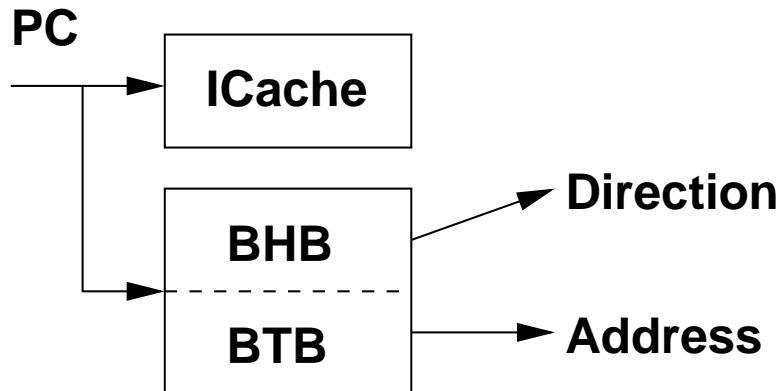
Two-Level BTB Entry with Global History Register





time

1	Br		
2	?	Br	
3	?	?	Br

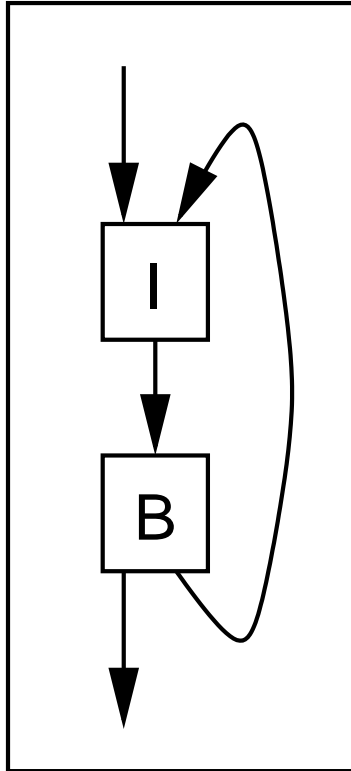


R2000/R3000: IF -> ID/IE
Compiler filled one delay slot.

R4000: IF -> ID -> IE
Two delay slots, but old code with one filled delay slot.
NOPs inserted in second slot.

R10000: OOO deep pipeline with branch prediction. Same old code. Delay slot must still be correctly handled which complicates IF and ID.

Speculative Update of Branch Predictors



First Sequence

I → B

BTB predicts instruction B to loop back

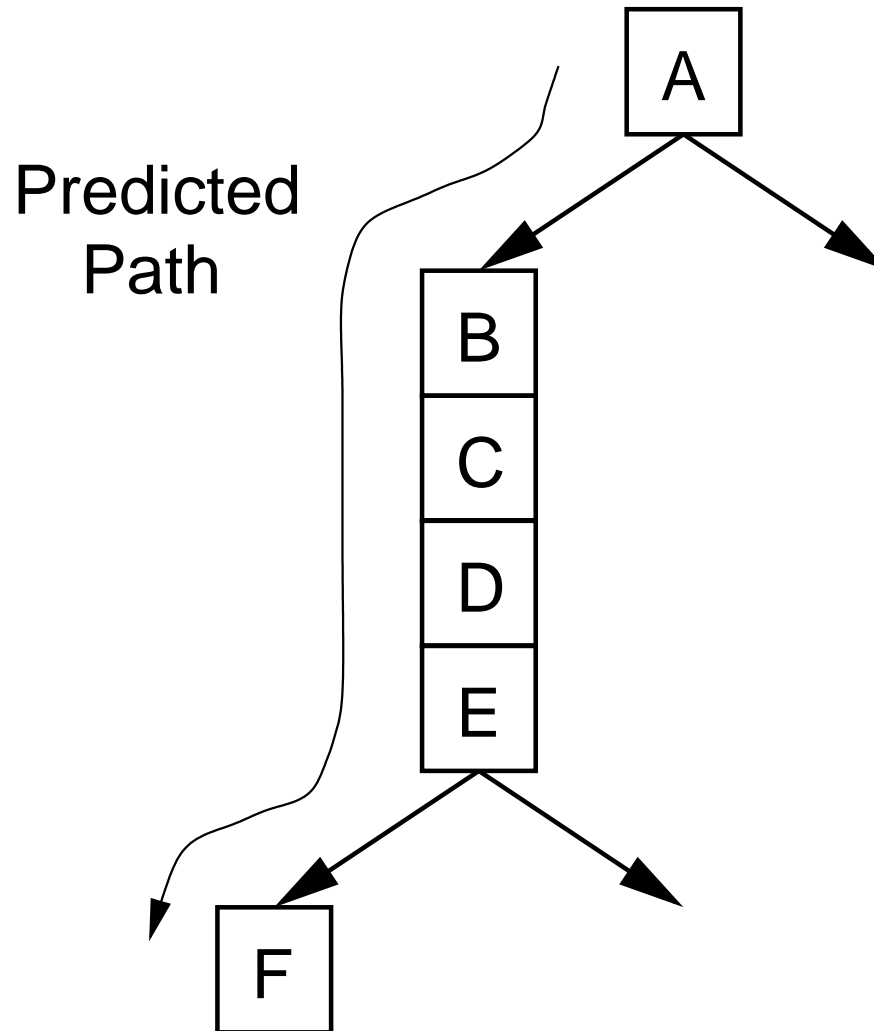
I → B → I → B

Another BTB prediction is required

I → B → I → B → I → B

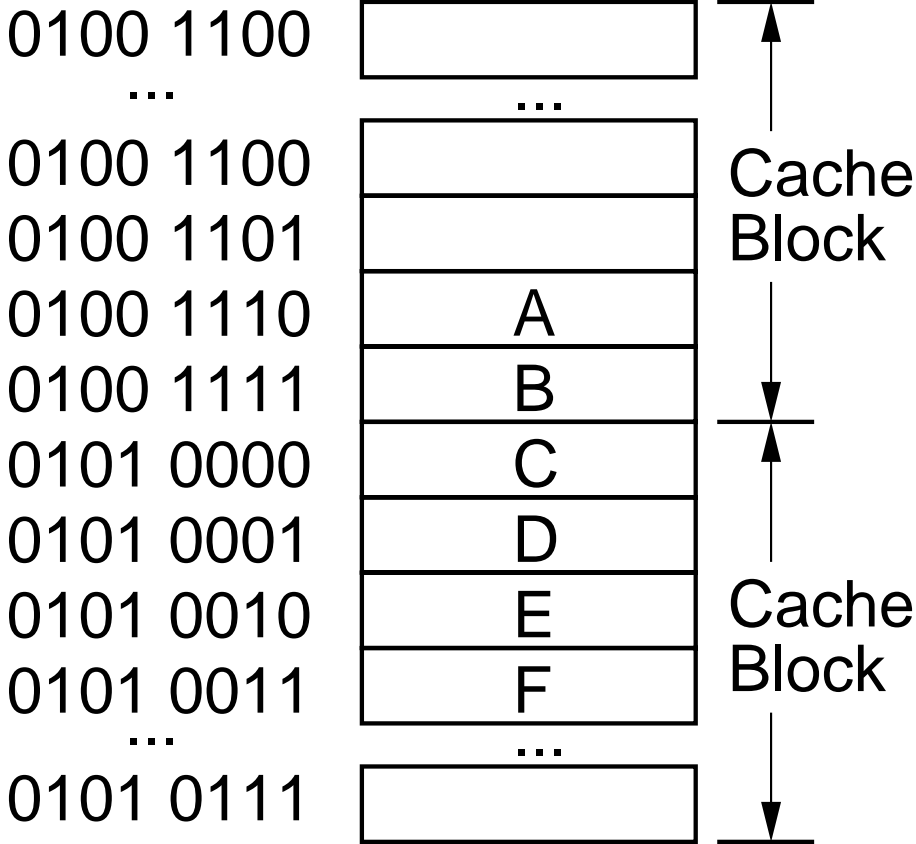
The second prediction is now based on
a BTB entry which has not been updated
by the first branch occurrence.

Example for Problems with Speculative Update of Branch Predictors

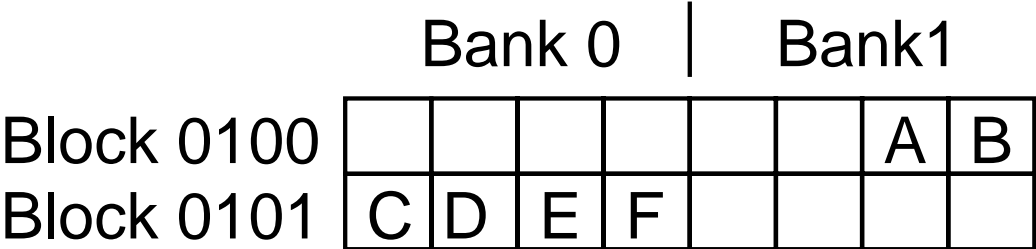


Cache Banking

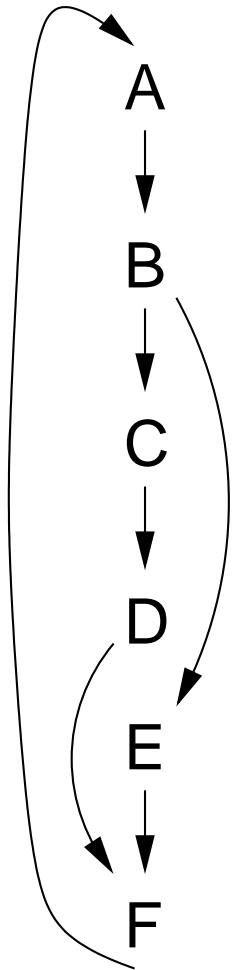
Memory Map



Cache

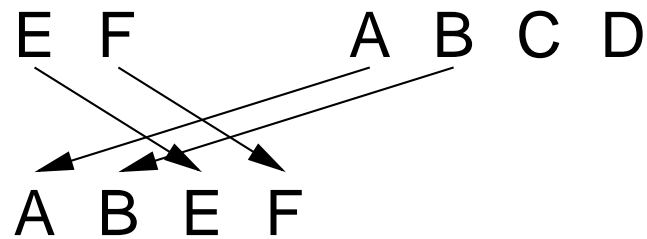


Short Distance Predict Taken Branches

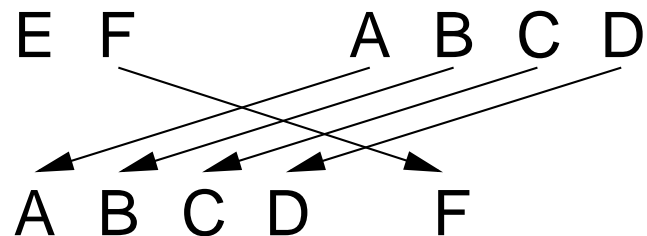


	Bank 0				Bank 1			
Block 0100					A	B	C	D
Block 0101	E	F						

First Iteration (Branch B taken to E)



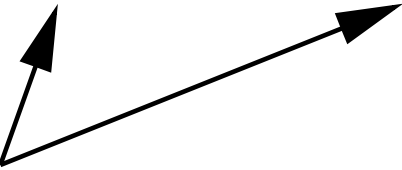
Second Iteration (Branch B fall through to C)




BTB Short/Long Distance Masks

Tag	Not Taken Taken Mask	Mask	Taken Address
	0 0 1 1 C D E F	1 1 0 1 C D E F	next seq. block

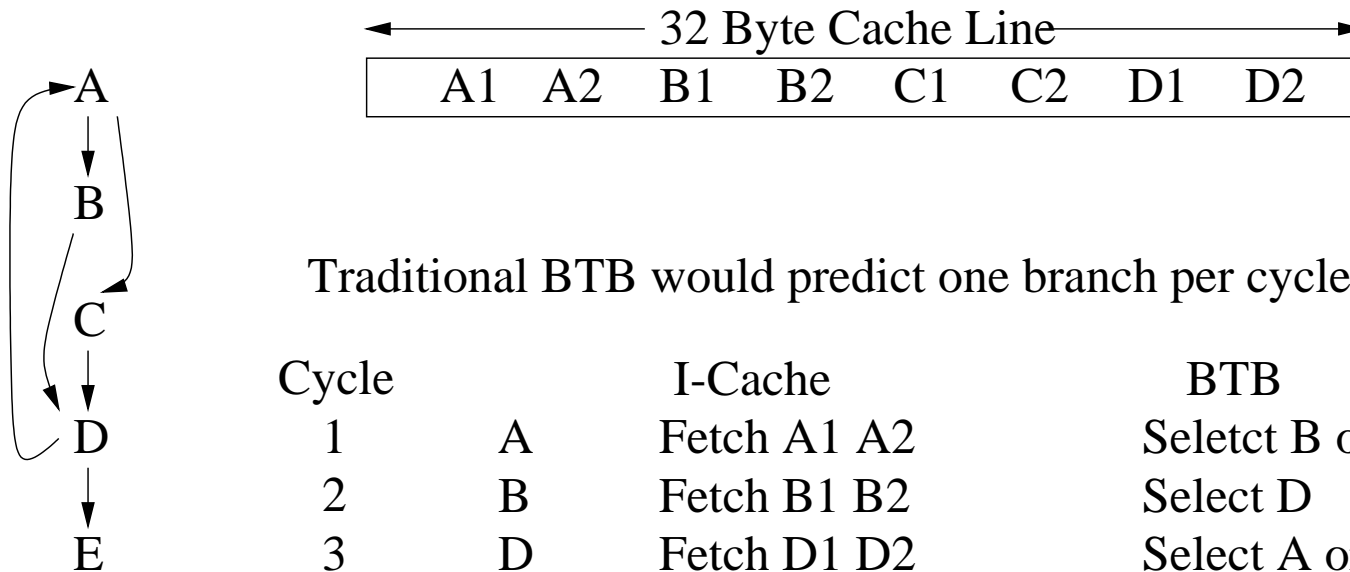
short distance branches



long distance branches



Example: A2 is not seldom taken Pattern: NTNTNTN



Traditional BTB would predict one branch per cycle

Cycle		I-Cache	BTB
1	A	Fetch A1 A2	Select B or C
2	B	Fetch B1 B2	Select D
3	D	Fetch D1 D2	Select A or E
4	A	Fetch A1 A2	Select B or C
5	C	Fetch C1 C2 D1 D2	Select A or E

Assume all correct predictions

12 instructions / 5 cycles = 2.4 average instructions/cycle

Would like to execute:

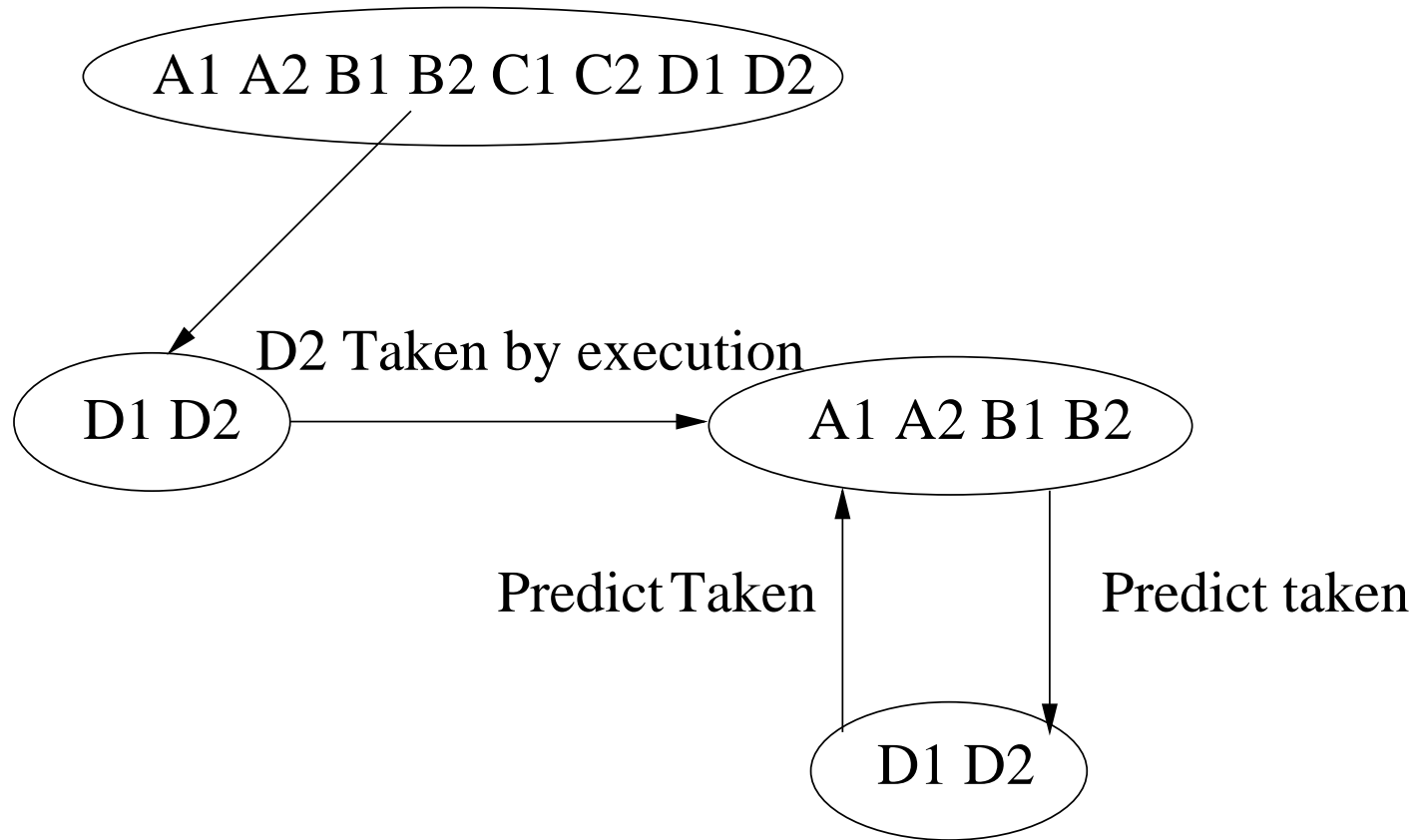
A1 A2 B1 B2 D1 D2

1 Cycle

A1 A2 C1 C2 D1 D2

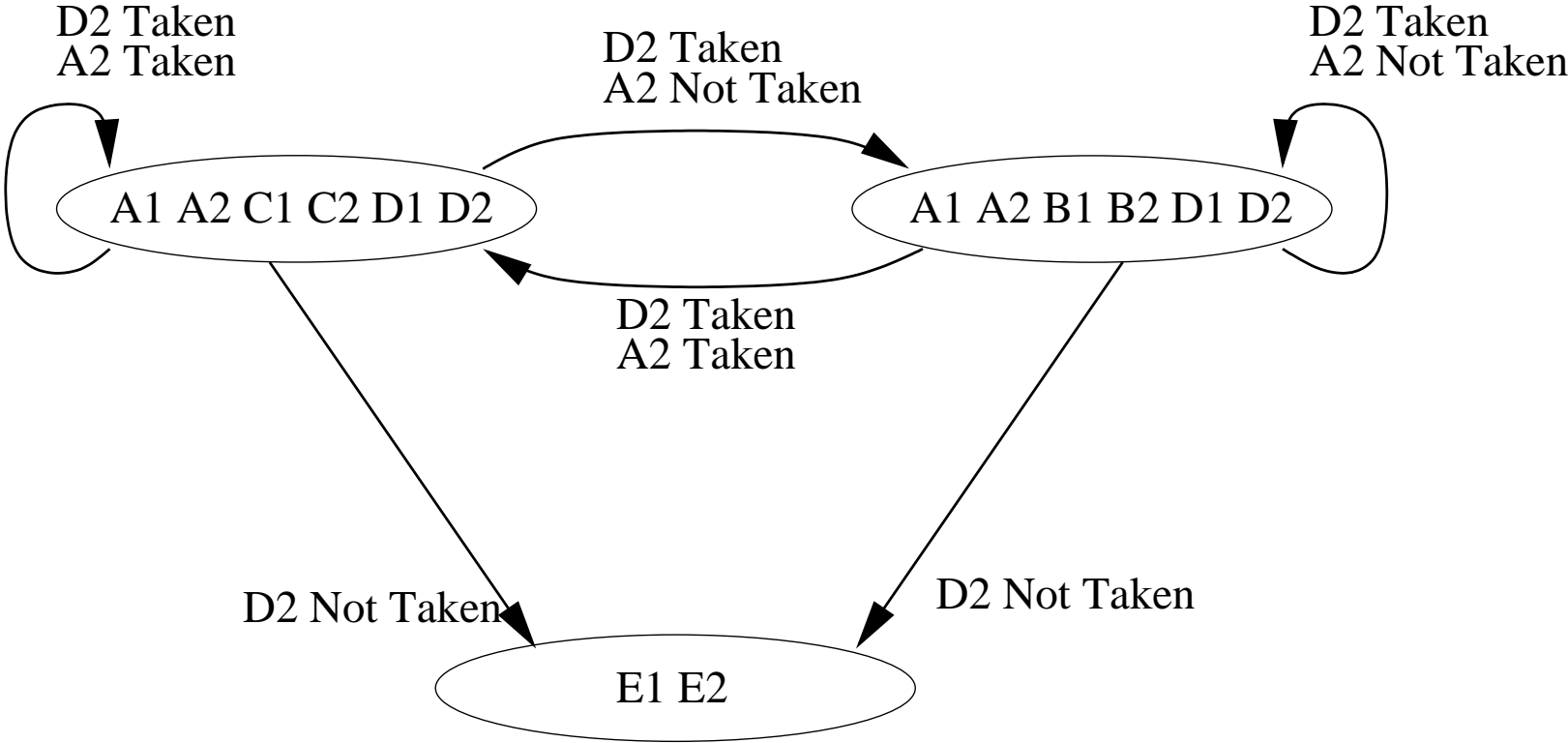
1 Cycle

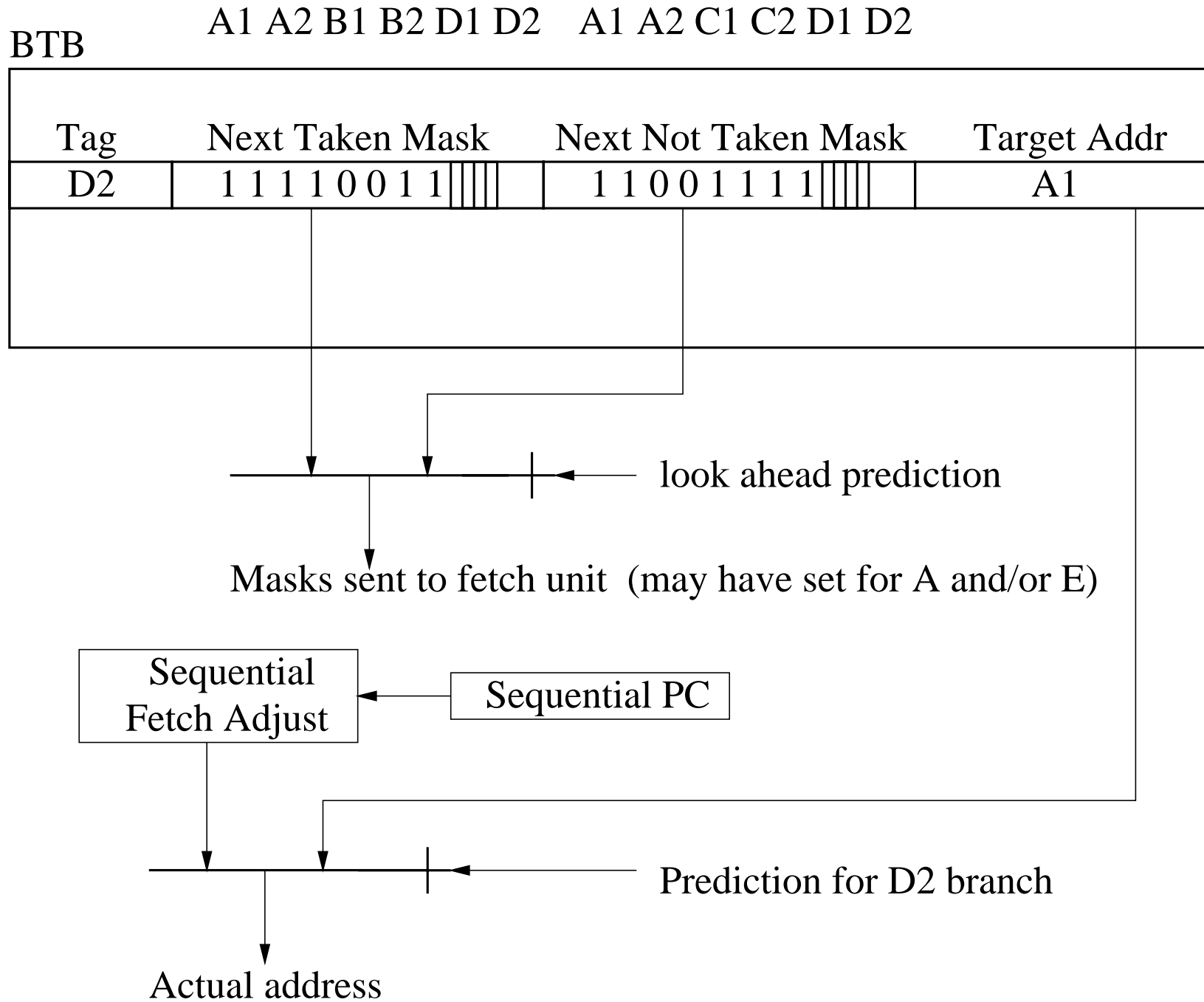
Example: A2 seldom taken



Example: Wide issue machine with BTB masks

STATE: Fetch patterns
TRANSITIONS: predictions





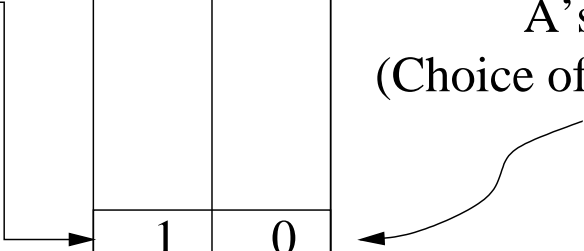
0 1 0 0 1 0 1 0 1 0 0 1 1

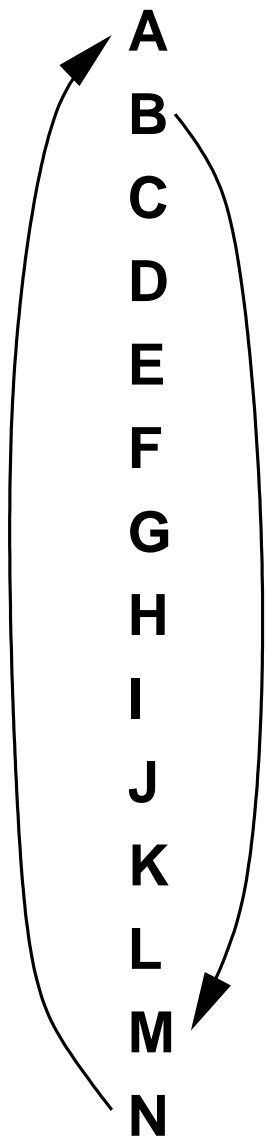
Branch D History
Pattern Register

Current Next

	Current	Next
	1	0

A's Prediction
(Choice of Short Distance Mask)





					A	B	C
D	E	F	G	H	I	J	K
L	M	N					

A B M N

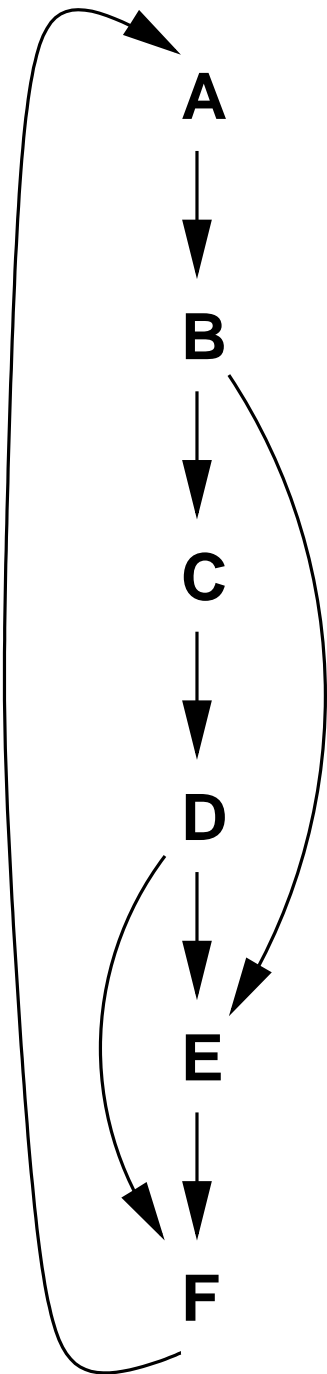


taken

A B C D E F



not taken



				A	B	C	D
E	F						

Fetch across back edge

A B E F A B C D F

