ER1 adapted for ER2

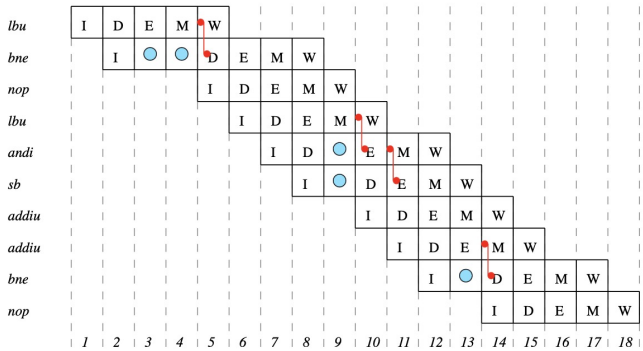
Original Code

Branch succeeds 80% of the time!

```
_For:
        Lbu   r8, 0(r4)
        Bne   r8, r6, _Endif
        Nop
         Lbu   r9, 1(r4)
         Andi  r9, r9, 0x01
         Sb    r9, 0(r7)
         Addiu r7, r7, 1
_Endif:
        Addiu r4, r4, 1
        Bne   r4, r5, _For
        Nop
```

Mips32 Implementation

Branch not taken (14 cycles)



20% of the time the branch is not taken

Branch taken (9 cycles)

Calculations MIPS32

$\#Cycles_{avg} = 0.8(9) + 0.2(14) = 7.2 + 2.8 = 10$
$\#Instructions = 10$
$\#Useful\ Instructions = 8$

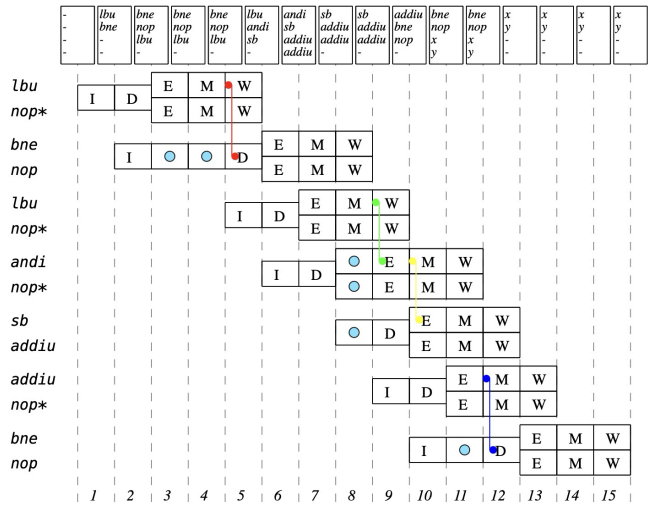
$$CPI = \frac{0.8(9) + 0.2(14)}{0.8(6) + 0.2(10)} = \frac{(7.2 + 2.8)}{(4.8 + 2)} = \frac{10}{6.8} = 1.47$$

$$CPI_u = \frac{0.8(9) + 0.2(14)}{0.8(4) + 0.2(8)} = \frac{(7.2 + 2.8)}{(3.2 + 1.6)} = \frac{10}{4.8} = 2.83$$

SS2 Implementation

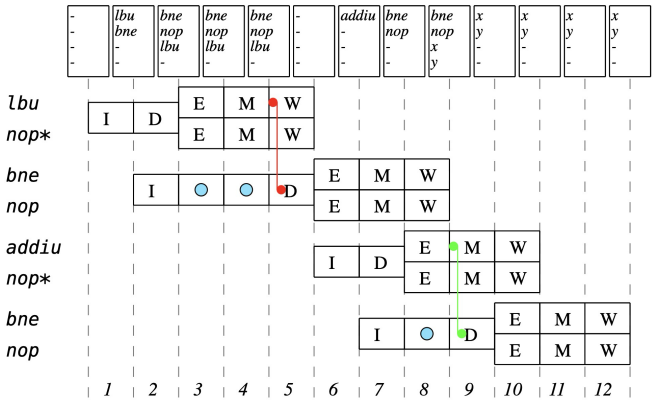
Branch not taken (12 cycles)

Branch fails 20% of the time



Branch taken (9 cycles)

Branch succeeds 80% of the time



Calculations SS2

$\#Cycles_{avg} = 0.8(12) + 0.2(9) = 11.4$
$\#Instructions = 10$
$\#Useful\ Instructions = 8$

$$CPI = \frac{11.4}{0.8(6) + 0.2(10)} = \frac{11.4}{(4.8 + 2)} = 1.67$$

$$CPI_u = \frac{11.4}{0.8(4) + 0.2(8)} = \frac{11.4}{(3.2 + 1.6)} = 2.37$$

Unrolled loop

```
_For:
        Lbu   r8, 0(r4)
        Bne   r8, r6, _Endif1
        Nop
         Lbu   r9, 1(r4)
         Andi  r9, r9, 0x01
         Sb    r9, 0(r7)
         Addiu r7, r7, 1
_Endif1:
    Lbu   r8, 1(r4)
        Bne   r8, r6, _Endif2
        Nop
         Lbu   r9, 2(r4)
         Andi  r9, r9, 0x01
         Sb    r9, 1(r7)
         Addiu r7, r7, 1
_Endif2:
        Addiu r4, r4, 2
        Bne   r4, r5, _For
        Nop
```

Software pipeline (Mips)

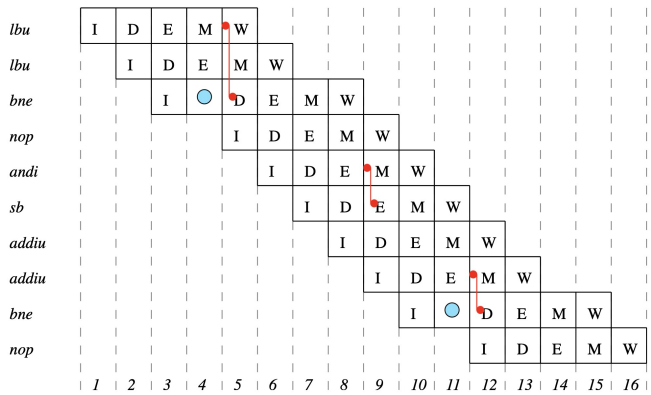
Software pipeline (SS2)

Modified Code

```
_For:
        Lbu   r8, 0(r4)
        Lbu   r9, (r4)
        Bne   r8, r6, _Endif
        Nop
         Andi  r9, r9, 0x01
         Sb    r9, 0(r7)
         Addiu r7, r7, 1
_Endif:
        Addiu r4, r4, 1
        Bne   r4, r5, _For
        Nop
```

Mips32 Implementation

Branch not taken (12 cycles)



20% of the time the branch is not taken

Branch taken (9 cycles)

Branch is taken 80% of the time

Calculations MIPS32

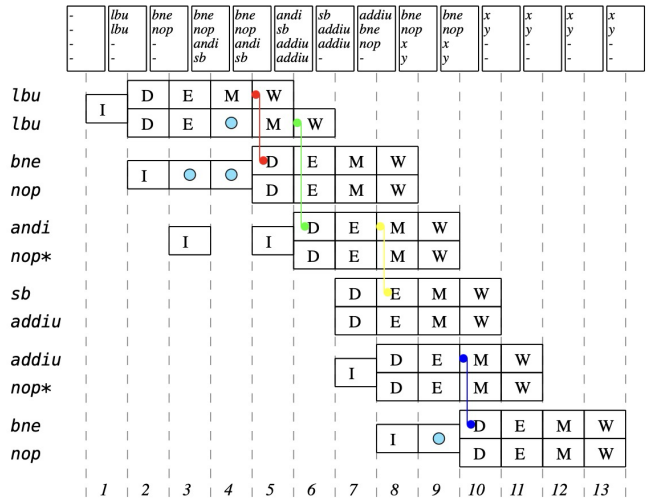
$\#Cycles_{avg} = 0.8(9) + 0.2(12) = 7.2 + 2.8 = 9.6$
$\#Instructions = 10$
$\#Useful\ Instructions = 8$

$$CPI = \frac{0.8(9) + 0.2(14)}{0.8(6) + 0.2(10)} = \frac{9.6}{6.8} = 1.41$$

$$CPI_u = \frac{0.8(9) + 0.2(14)}{0.8(4) + 0.2(8)} = \frac{9.6}{4.8} = 2$$

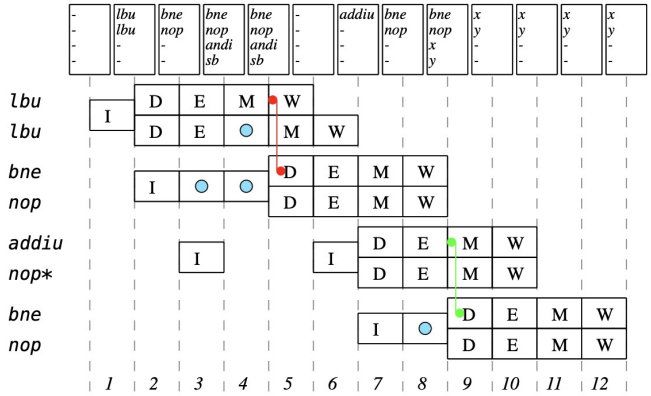
SS2 Implementation

Branch not taken (10 cycles)



20% of the time

Branch taken (9 cycles)



80% of the time

Calculations SS2

$\#Cycles_{avg} = 0.8(9) + 0.2(10) = 9.2$
$\#Instructions = 10$
$\#Useful\ Instructions = 8$

$$CPI = \frac{9.2}{0.8(6) + 0.2(10)} = \frac{9.2}{(4.8 + 2)} = 1.35$$

$$CPI_u = \frac{9.2}{0.8(4) + 0.2(8)} = \frac{9.2}{(3.2 + 1.6)} = 1.91$$

Unrolled loop

```
_For:
        Lbu   r8, 0(r4)
        Lbu   r9, 1(r4)
        Bne   r8, r6, _Endif1
        Nop
         Andi  r9, r9, 0x01
         Sb    r9, 0(r7)
         Addiu r7, r7, 1
_Endif1:
        Lbu   r8, 1(r4)
        Lbu   r9, 2(r4)
        Bne   r8, r6, _Endif2
        Nop
         Andi  r9, r9, 0x01
         Sb    r9, 1(r7)
         Addiu r7, r7, 1
_Endif2:
        Addiu r4, r4, 2
        Bne   r4, r5, _For
        Nop
```

Software pipeline (Mips)

Software pipeline (SS2)