SCEV
Establishing Pre and Post Conditions

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SCEV:

Scaler **Ev**olution: Technique to understand how variables change with execution.

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Example: Generate set of conditions required to establish loop is safe to run.

Safety Properties:

(1) Loop terminates

(2) Memory access are in bounds

C[100] = {...} ; x = 99; C[x] //safe; C[x + 1] //unsafe

SCEV: Example

```
for (j = 0; j < 300; j++) {
     if (j & 1) {
        m = PT_REGS_RC(ctx);
        i = m + j;
      } else {
        m = j;
      }
      sum += i * m;
}
```

SCEV: Example

```
 r4 = 0
 r2 = 0
 r3 = 0
 goto +10 <LBB0_1>
LBB0_3:
 r0 *= r3
 r0 += r4
 r2 += 1
 r5 = r2
 r5 <<= 32
 r5 >>= 32
 r4 = r0
 if r5 != 300 goto +2 <LBB0_1>
end_loop
exit
```

```
LBB0_1:
 r5 = r2
 r5 &= 1
 r0 = r2
 if r5 == 0 goto -14 <LBB0_3>
 r0 = *(u64 *)(r1 + 80)
 r3 = r2
 r3 += r0
 goto -18 <LBB0_3>
```

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 r4 = 0
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LBB0_1:
 r5 = r2                                   r5: ( _ , mov, r2)
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```
LBB0_1:
 r5 = r2                                  r5: ( _ , mov, r2)
 r5 &= 1                                  r5: ( _ , mov, r2, &, 1)
 r0 = r2                                  r0: ( _ , =, r2)
 if r5 == 0 goto -14 <LBB0_3>     ???
 r0 = *(u64 *)(r1 + 80)
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 r0 += r4                    r0: ( _ , =, r2, *, r3, +, r4)
 r2 += 1                     r2: ( _ , +, 1)
 r5 = r2                     r5: ( _ , =, r2)
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 r5 = r2              r5: ( _ , =, r2) ► (_, +, 1)
 r5 <<= 32
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 r2 += 1                           r2: ( _ , +, 1)
 r5 = r2          r5: ( _ , =, r2) ► r5': (_, +, 1)
 r5 <<= 32                         r5': (_, +, 1, << 32)
 r5 >>= 32                         r5': (_, +, 1, >> 32)
 r4 = r0                           r4: (_, =, r0)
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LBB0_1:
 r5 = r2                           r5: ( _ , =, r2)
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 r0 += r4                                  r0: ( _ , =, r2, *, r3, +, r4)
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 r5 = r2                 r5: ( _ , =, r2) ► r5': (_, +, 1)
 r5 <<= 32                                 r5': (_, +, 1, << 32)
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 r4 = r0                                   r4: (_, =, r0)
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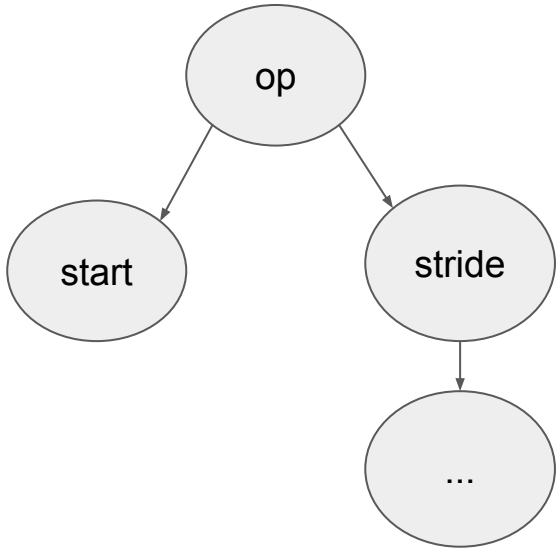

SCEV: Example

REG#0: (<unknown>, unknown (MOV), <>)
REG#1: (none)
REG#2: (<unknown>, add, 1)
REG#3: (<unknown>, add (MOV), REG0)
REG#4: (<unknown>, unknown (MOV), <>)
REG#5: (<unknown>, add, 1)
REG#6: (none)
REG#7: (none)
REG#8: (none)
REG#9: (none)
REG#10: (none)

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REG#5: (<unknown>, add, 1)
REG#6: (none)
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REG#0: (<unknown>, unknown (MOV), <>)
REG#1: (none)
REG#2: (<unknown>, add, 1)
REG#3: (<unknown>, add (MOV), REG0)
REG#4: (<unknown>, unknown (MOV), <>)
REG#5: (<unknown>, add, 1)
REG#6: (none)
REG#7: (none)
REG#8: (none)
REG#9: (none)
REG#10: (none)

TBD: implement ‘*’ operator logic

SCEV: Example

```
 r3 = 0
...
if r5 != 300 goto +2 <LBB0_1>
```

REG#5: (<unknown>, add, 1)

Terminate?

(a) Is r5 monotonic? Yes
(b) Tripcount, 300
(c) Memory safe? Yes

SCEV: Details

SCEV Foldings:

(x, +, a, +, b) ➔ (x, + (a+b))

SCEV: Details

Memory Safety in general:

(1) When we see memory read/write push entire state on to stack with reference

(2) Complete SCEV pass, calculate trip count

(3) Check memory access from stack

SCEV: Details

BPF stack:

Track register + stack_slot so that all expressions are unique.

(reg#, slot) → (REG#5, curr): (<unknown>, add, 1)

SCEV: What Else

- Operators &, |, >>, <<, need a solution for folding
- Works for loops, lets try functions
- Testing and more testing
- SCEV implement folding operations

Thanks! Questions?