NERSC/LBNL UPC Compiler Status Report

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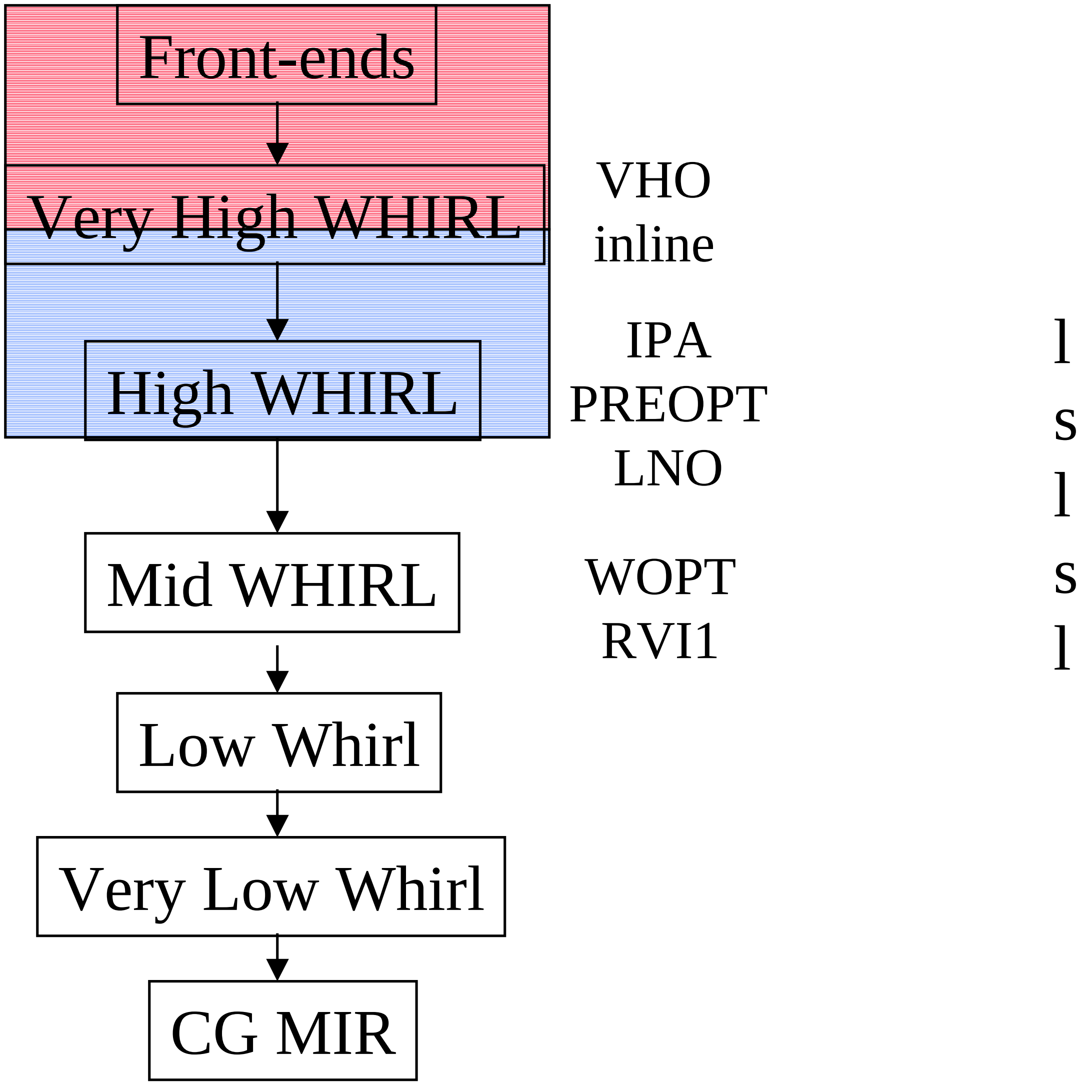
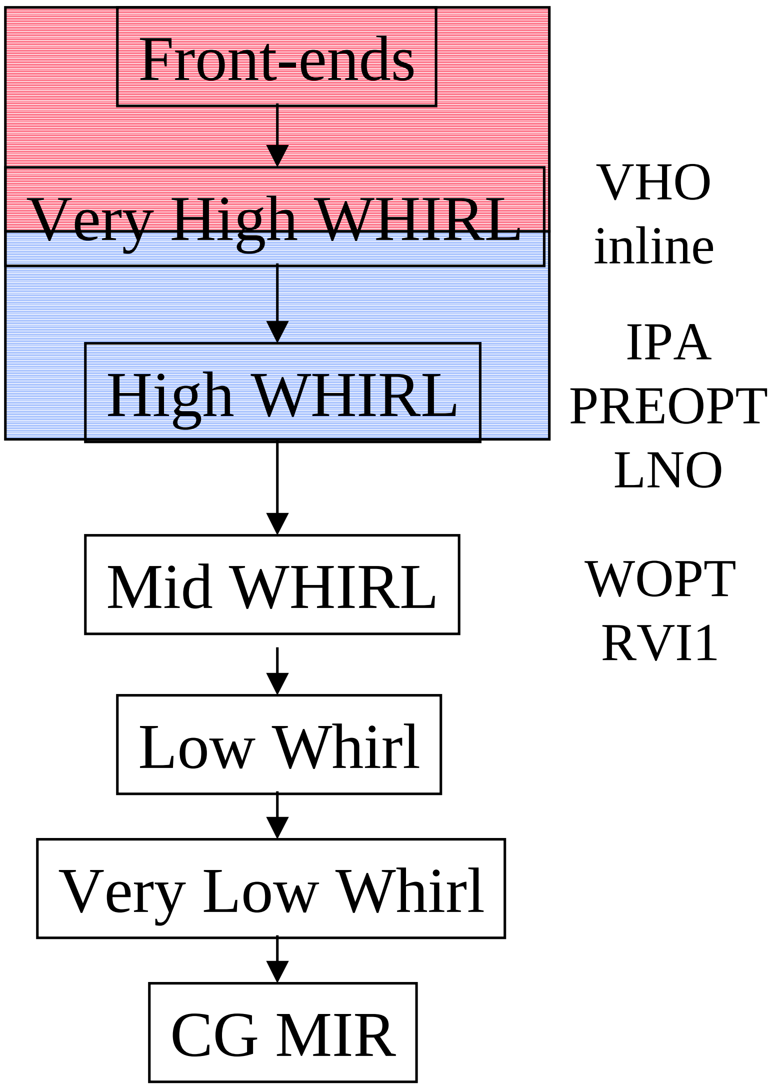
UPC Compiler – Status Report

- **Current Status:**
  - **UPC-to-C translator implemented in open64. Compliant with rev 1.0 of the UPC spec.**
  - **"Translates" the GWU test suite and test programs from Intrepid.**

UPC Compiler – Future Work



UPC Compiler – Future Work



- **Integrate with GasNet and the UPC runtime**
- **Test runtime and translator (32/64 bit)**
- **Investigate interaction between translator and optimization packages (legal C code)**
- **UPC specific optimizations**
- **Open64 code generator**

UPC Optimizations - Problems

- Shared pointer - logical tuple (addr, thread, phase)

```
{void *addr; int thread; int phase;}
```

- Expensive pointer arithmetic and address generation

```
p+i ->   p.phase=(p.phase+i)%B
         p.thread=(p.thread+(p.phase+i)/B)%T
```

- Parallelism expressed by `forall` and affinity test

- Overhead of fine grained communication can become prohibitive

Translated UPC Code

```
#include <upc.h>
shared float *a, *b;

int main() {
  int i, k ;
upc_forall(k=7; k <234; k++; &a[k]) {
    upc_forall(i = 0; i < 1000; i++; 333) {
        a[k] = b[k+1];
    }
  }
}
```

```
k = 7;
while(k <= 233)
{
  Mreturn_temp_0 = upcr_add_shared(a.u0, 4, k, 1);
  __comma1 = upcr_threadof_shared(Mreturn_temp_0);
  if(MYTHREAD == __comma1)
  {
    i = 0;
    while(i <= 999)
    {
      Mreturn_temp_2 = upcr_add_shared(a.u0, 4, k, 1);
      Mreturn_temp_1 = upcr_add_shared(b.u0, 4, k + 1, 1);
      __comma = upcr_get_nb_shared_float(Mreturn_temp_1, 0);
      __comma0 = upcr_wait_syncnb_valget_float(__comma);
      upcr_put_nb_shared_float(Mreturn_temp_2, 0, __comma0);
      _3 :;
      i = i + 1;
    }
  }
  _2 :;
  k = k + 1;
}
……..
```

UPC Optimizations

- "Generic" scalar and loop optimizations (unrolling, pipelining…)

- Address generation optimizations
  - Eliminate run-time tests
    - Table lookup / Basis vectors
  - Simplify pointer/address arithmetic
    - Address components reuse
    - Localization

- Communication optimizations
  - Vectorization
  - Message combination
  - Message pipelining
  - Prefetching for irregular data accesses

Run-Time Test Elimination

- Problem – find sequence of local memory locations that processor P accesses during the computation

- Well explored in the context of HPF

- Several techniques proposed for for block-cyclic distributions:
  - table lookup (Chatterjee,Kennedy)
  - basis vectors (Ramanujam, Thirumalai)

- UPC layouts: cyclic, pure block, indefinite block size - particular case of block cyclic

Table Array Address Lookup

```
upc_forall(i=l; i<u; i+=s; &a[i])
   a[i] = EXP();
```

```
i=l;
while(i<u) {
   t_0 = upcr_add_shared(a, 4, i, 1);
  __comma1 = upcr_threadof_shared(t_0);
  if(MYTHREAD == __comma1) {
    t_2 = upcr_add_shared(a.u0, 4, i, 1);
    upcr_put_shared_float(t_2, 0, EXP());
  }
 _1:
 i+= s;
}
```

UPC to C translation

```
compute T, next, start
base = startmem;
i = startoffset;
while (base < endmem) {
  *base = EXP();
  base += T[i];
  i = next[i];
}
```

Table based lookup

(Kennedy)

Array Address Lookup

- Encouraging results – speedups between 50:200 versus run-time resolution
- Lookup – time vs space tradeoff . Kennedy introduces a demand-driven technique
- UPC arrays – simpler than HPF arrays
- UPC language restrictions – no aliasing between pointers with different block sizes
- Existing HPF techniques also applicable to UPC pointer based programs

Address Arithmetic Simplification

- Address Components Reuse
  - Idea – view shared pointers as three separate components (A, T, P) : (addr, thread, phase)
  - Exploit the implicit reuse of the thread and phase fields

- Pointer Localization
  - Determine which accesses can be performed using local pointers
  - Optimize for indefinite block size

- Requires heap analysis/LQI and a similar dependency analysis to the lookup techniques

Communication Optimizations

- Message Vectorization – hoist and prefetch an array slice.
- Message Combination – combine messages with the same target processor into a larger message
- Communication Pipelining – separate the initiation of a communication operation by its completion and overlap communication and computation

Communication Optimizations

- Some optimizations are complementary
- Choi&Snyder (Paragon/T3D -PVM/shmem), Krishnamurthy (CM5), Chakrabarti (SP2/Now)
- Speedups in the range 10%-40%
- Optimizations more effective for high latency transport layers (PVM/Now) ~ 25% speedup vs 10% speedup (shmem/SP2)

Prefetching of Irregular Data Accesses

- ❑ For serial programs – hide cache latency

- ❑ “Simpler” for parallel programs – hide communication latency

- ❑ Irregular data accesses
  - Array based programs : `a[b[i]]`
  - Irregular data structures (pointer based)

Prefetching of Irregular Data Accesses

- Array based programs
  - Well explored topic (“inspector-executor” – Saltz)

- Irregular data structures
  - Not very well explored in the context of SPMD programs.
  - Serial techniques: jump pointers, linearization (Mowry)
  - Is there a good case for it?

Conclusions

- We start with a clean slate
- Infrastructure for pointer analysis, array dependency analysis already in open64
- Communication optimizations and address calculation optimizations share common analyses
- Address calculation optimizations are likely to offer better performance improvements at this stage

The End

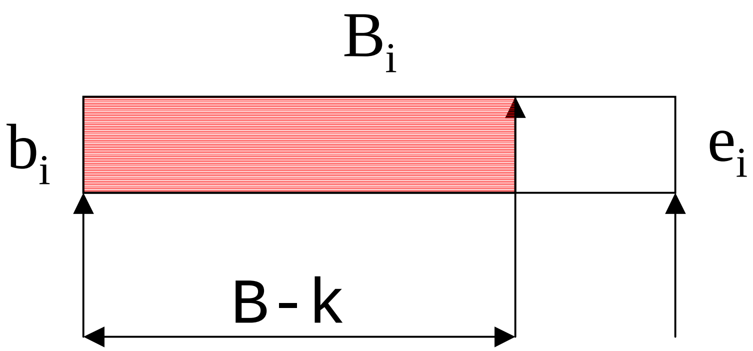
Address Arithmetic Simplification

- **Address Components Reuse**
  - **Idea – view shared pointers as three separate components (A, T, P) : (addr, thread, phase)**
  - **Exploit the implicit reuse of the thread and phase fields**

```
shared [B] float a[N],b[N]
upc_forall(i=l;i<u;i+=s;&a[i])
    a[i] = b[i+k];
```

Address Component Reuse

B1	B2	B3	B4	B5	B6
P0			P1		



$T_a = T_b$

$P_b = P_a + k$

```
a[i] = b[i+k];
```

$a \rightarrow (A_a, T_a, P_a)$

$b \rightarrow (A_b, T_b, P_b)$

Address Component Reuse

```
Ta = 0;
for (i=first_block; i<last_block; i=next_block) {
  for(j=bi,Pa=0; j < ei-k; j++,Pa++)
    put(Aa,Ta,Pa, get(Ab,Ta,Pa+k));
  ………
  for(; j<ei; j++)
     put(Aa,Ta,Pa, get(Ab,Ta+1,Pa-j));
  ………
}
```