From AAPC to
Random Permuters and Sorters

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Outline

AAPC: All to All Personalized Communication

- Congestion controlled AAPC routing
    - Quantify benefits and practical aspects (T3D)
- Memory operations in element permutations
    - Quantify difference between AAPC of blocks and true permutation of elements
- Sorting performance
    - Derive performance from an architectural model instead of measured implementation

AAPC Algorithms

- Conventional AAPC
  - Independent loop through all destinations
  - Router resolves congestion dynamically
  - Performance of AAPC: average over routes
- Phased AAPC
  - Synchronized loop through *k* phases/patterns
  - Congestion resolved statically
  - Performance of AAPC: slowest route determines phase; after that average over phases

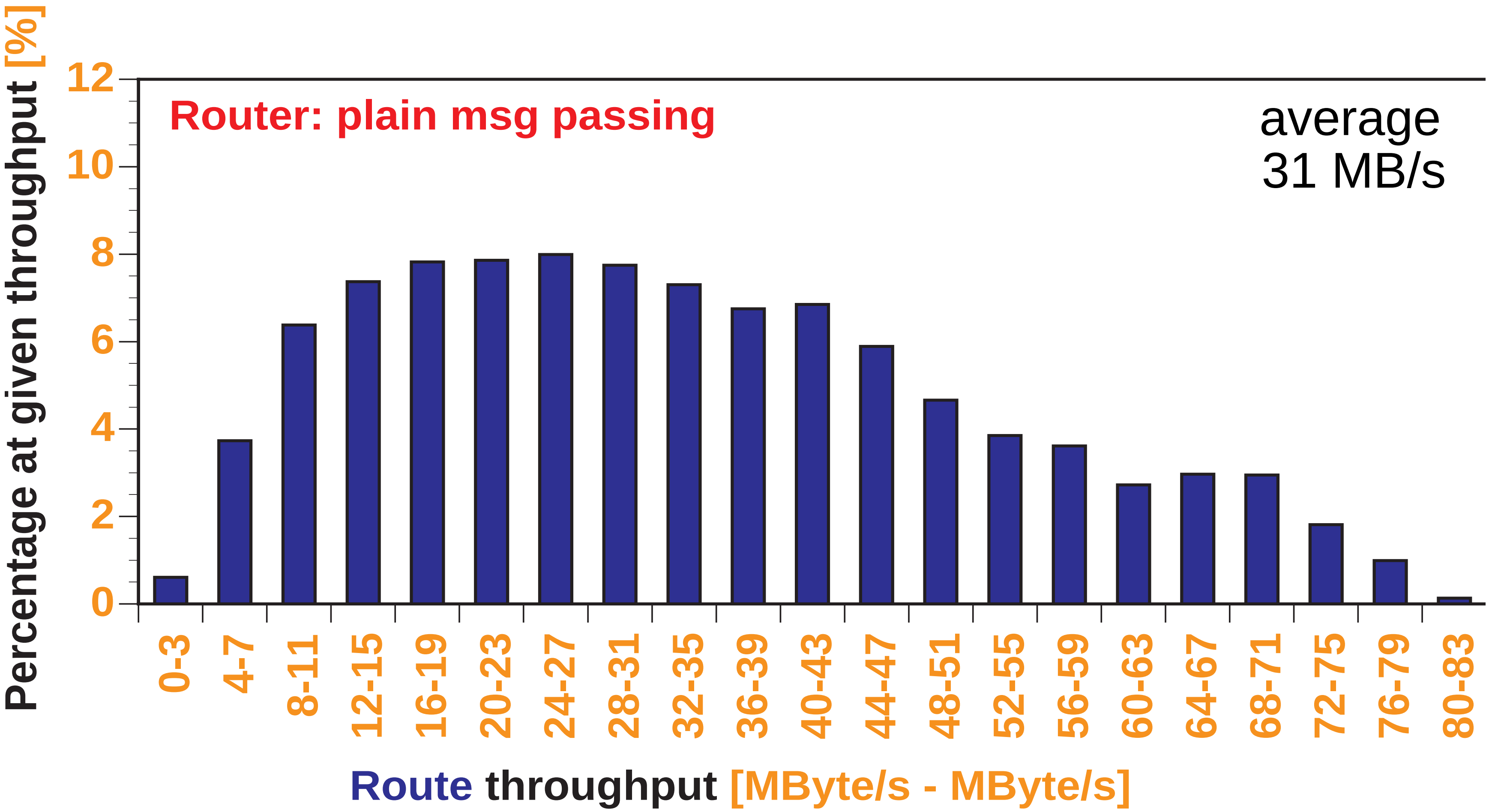
Target Architecture

Cray T3D with 512 nodes at the PSC:

- Topology 8x4x8x2 torus
- Non adaptive, dimension order routing on a 3-dimensional torus
- Short messages: 32 bytes pay load
- Fast links (2*75 MB/s per link raw speed)

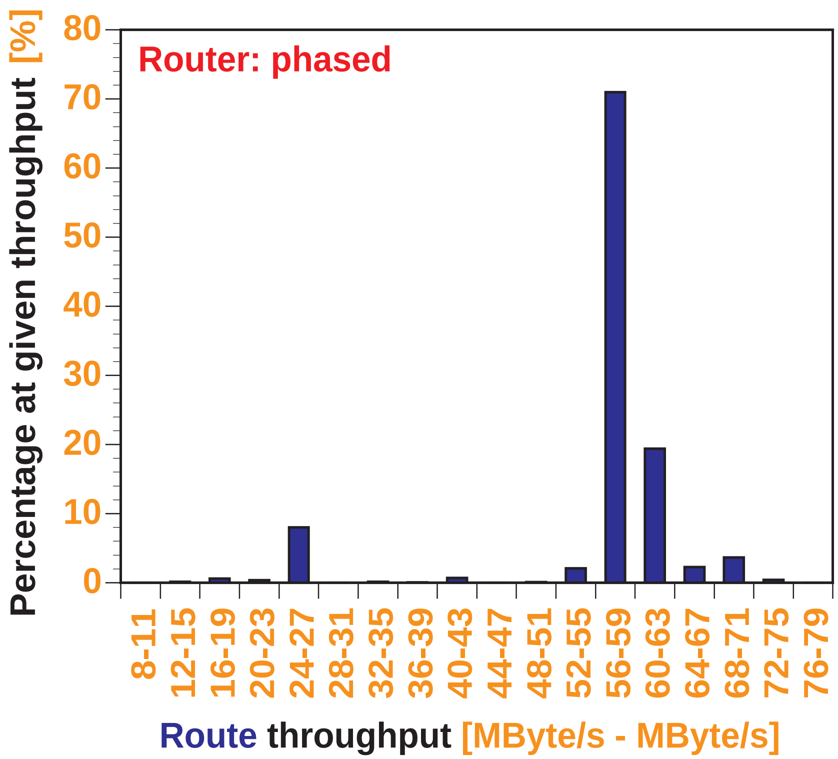
AAPC in Hell

(default routing - no phases)

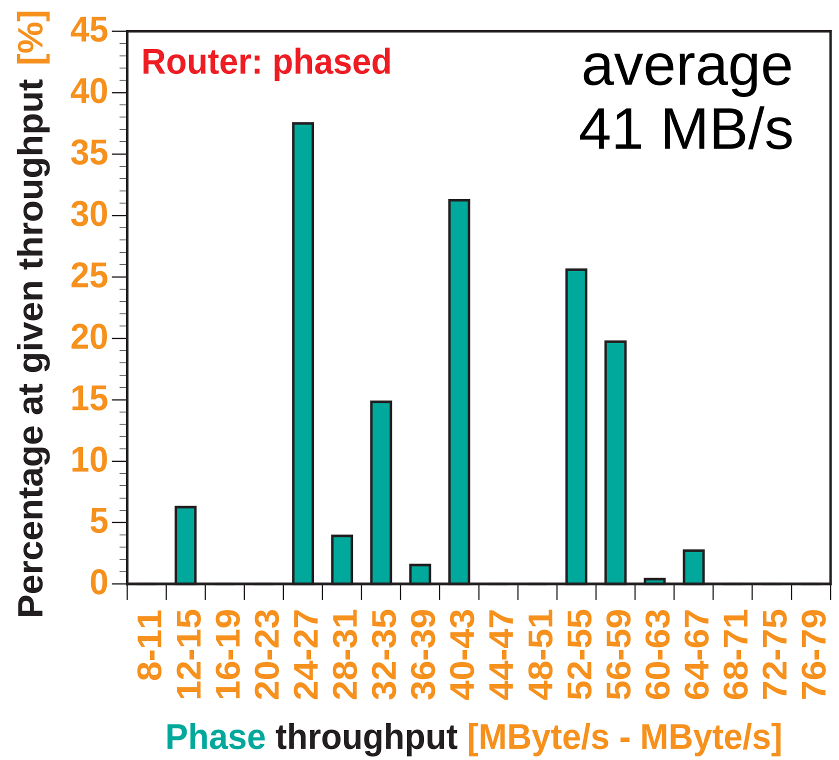


AAPC in Purgatory:

(phased routing with simple 3-dimensional patterns)



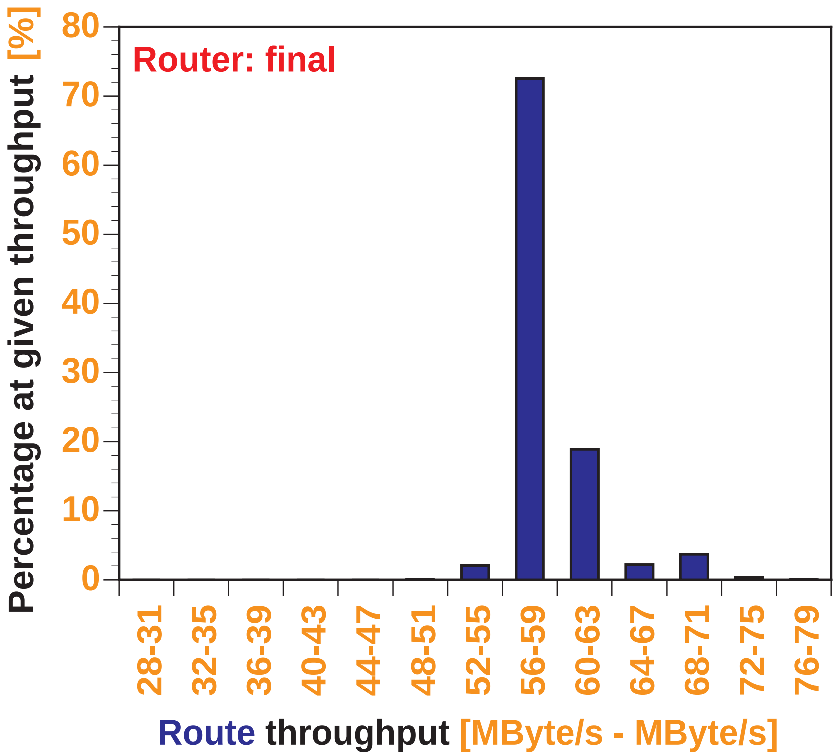
Throughput distribution over 262k routes



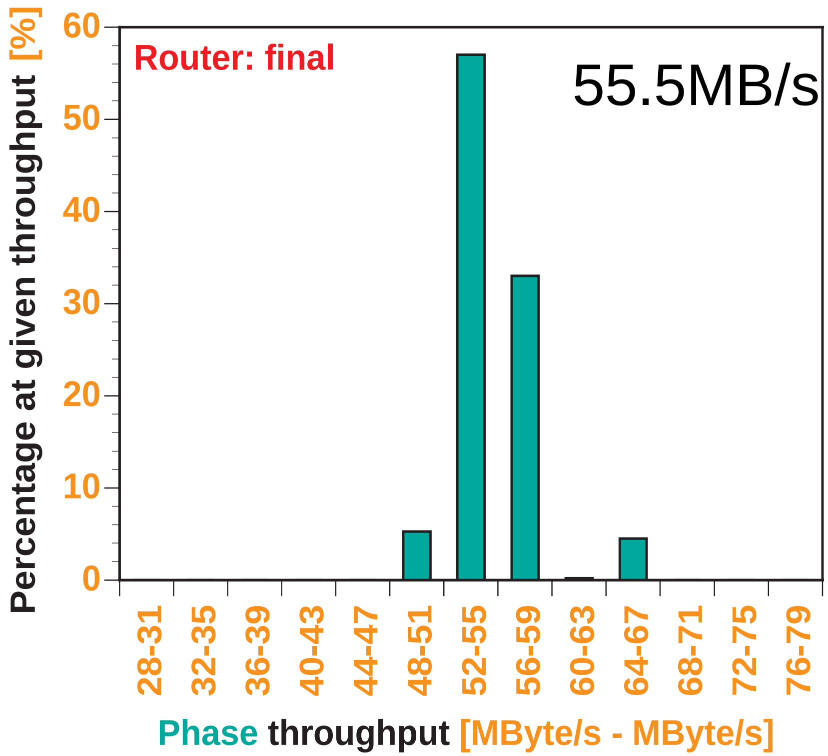
Throughput distribution over 512 phases

AAPC in Heaven:

(congestion free - after modified pattern and router)



Throughput distribution
over 262k routes



Throughput distribution
over 512 phases

Performance Impact of Congestion Controlled AAPC Routing

Balanced AAPC on 512 node T3D			
Algorithm	MBytes/s per node	MByte/s aggregate	Percent of Limit
No phases	31.1	15,945	41%
Phased	41.4	21,200	55%
Pattern fixed	46.7	23,910	62%
Router fixed	54.4	27,852	73%
Final	55.5	28,416	74%
Hardware	75.0	38,400	100%

Options for Element Permutations

- **Buffer-packing transfers**
  - Pack buffer (gather)
  - Transfer data across network, AAPC of blocks
  - Unpack buffer (scatter)
- **Chained transfers**
  - Pack - transfer - unpack

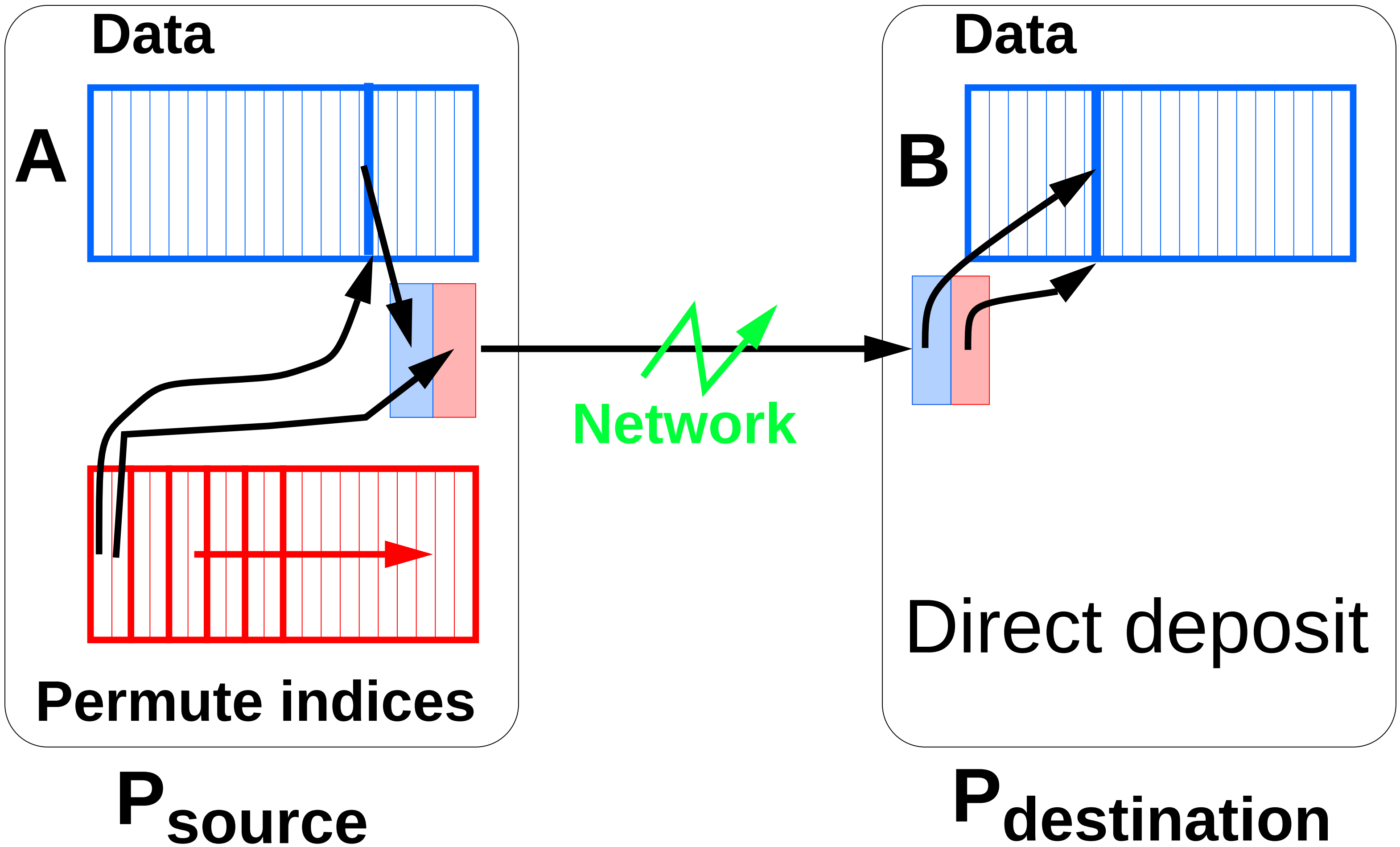
On a Cray T3D:

Buffer packing: 14 MB/s - Chained: 32 MB/s

Trade-offs described in Stricker/Gross ISCA95

Element Permutations (B=Perm[A])

(routed on a message passing machine)



Performance of Element Permutations

(including memory operations)

	Model	Measured on 512 node T3D		
AAPC type	MBytes/s per proc.	MBytes/s per proc.	MByte/s aggregate	Percent of Limit
Blocks	69	55.5	28,416	74%
Transpose	38	29.5	15,104	39%
Random Permute	32	22.0	11,264	29%

Motivation for Modelling Steps of Sorters

- Recent algorithmic work:
  - Bucket work vs. key work [Blelloch, Zagha]
  - Balanced transposes vs. unbalanced permutes [Bader, Helman, Jájá]
- Previous implementation work:
  - Measured implementations
  - Indirect connection to node architecture
- Copy transfer model:
  - Analytic model
  - Direct connection to architectural features

Modelling Radix Sort Performance

Primitive	Model work	Model MByte/s	Measured MByte/s
Bucket Counting	key	21	14
Local Permutation	key	21	8
Global Permutation	key	32	20
Bucket Transpose	bucket	38	20
Bucket Reduction	bucket	220	125
Bucket Scan	bucket	90	60
Bucket Untranspose	bucket	38	20

Model: 7.88 MB/s per processor

Measured: 3.99 MB/s per processor, 2042 MB/s total, 255 million keys/s (16bit key, 48bit data)

Conclusions

- Difficult to achieve hardware performance on AAPC routing of blocks.
  - Increase from 41% of nominal peak to 74%
  - Hiding net topology details is not a good idea!
- Cost of memory operations in permutations.
  - Element permutations at 29% of peak
  - Memory operations are significant!
- Estimated sorting performance with copy transfer model
  - Local memory operations are dominant costs!

Simple Radix Sorter

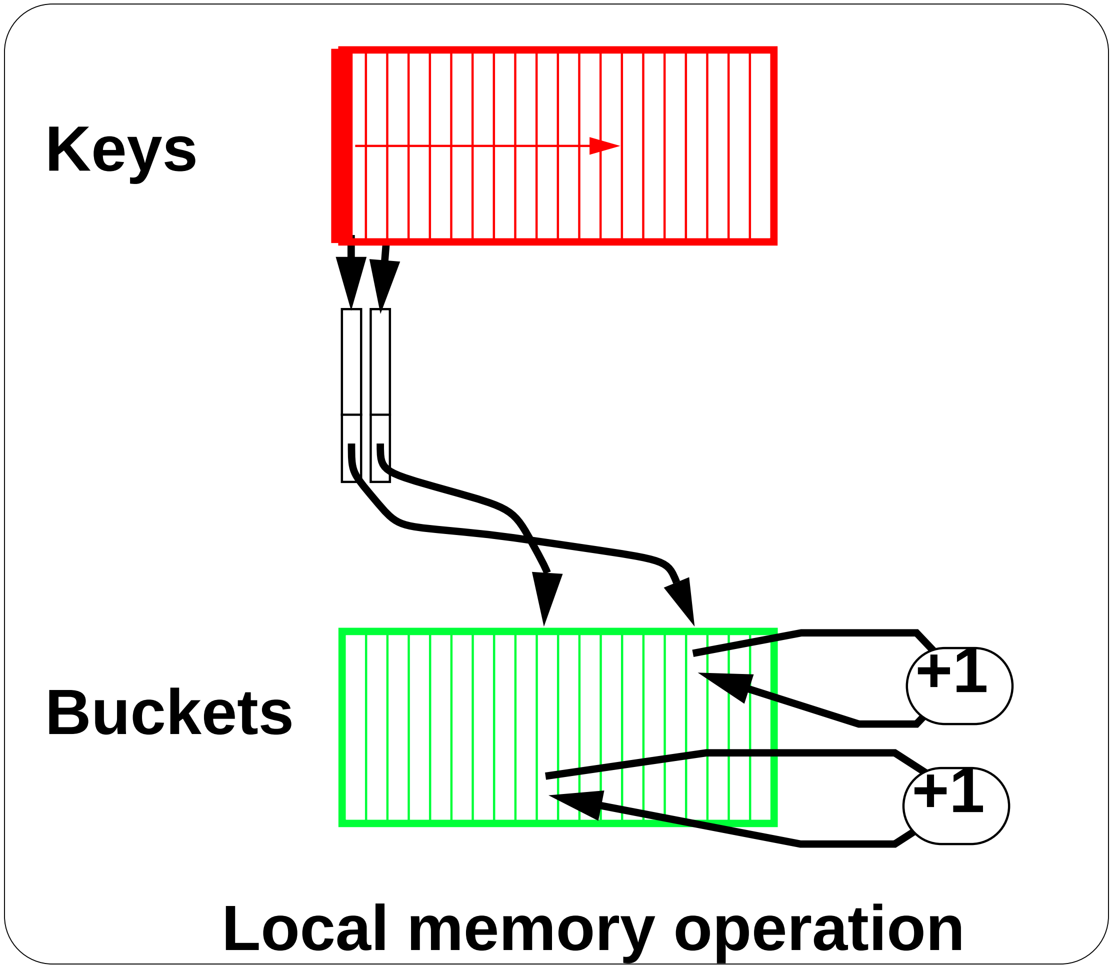
- for (i=0; i<radix_steps; i++)

  1: B=bucket_counts(A)
  2: transpose(B)
  3: B'=prefix_scan(B)
  4: transpose(B')
  5: A'=presort_copy(A,B')
  6: A=grouped_permute(A')

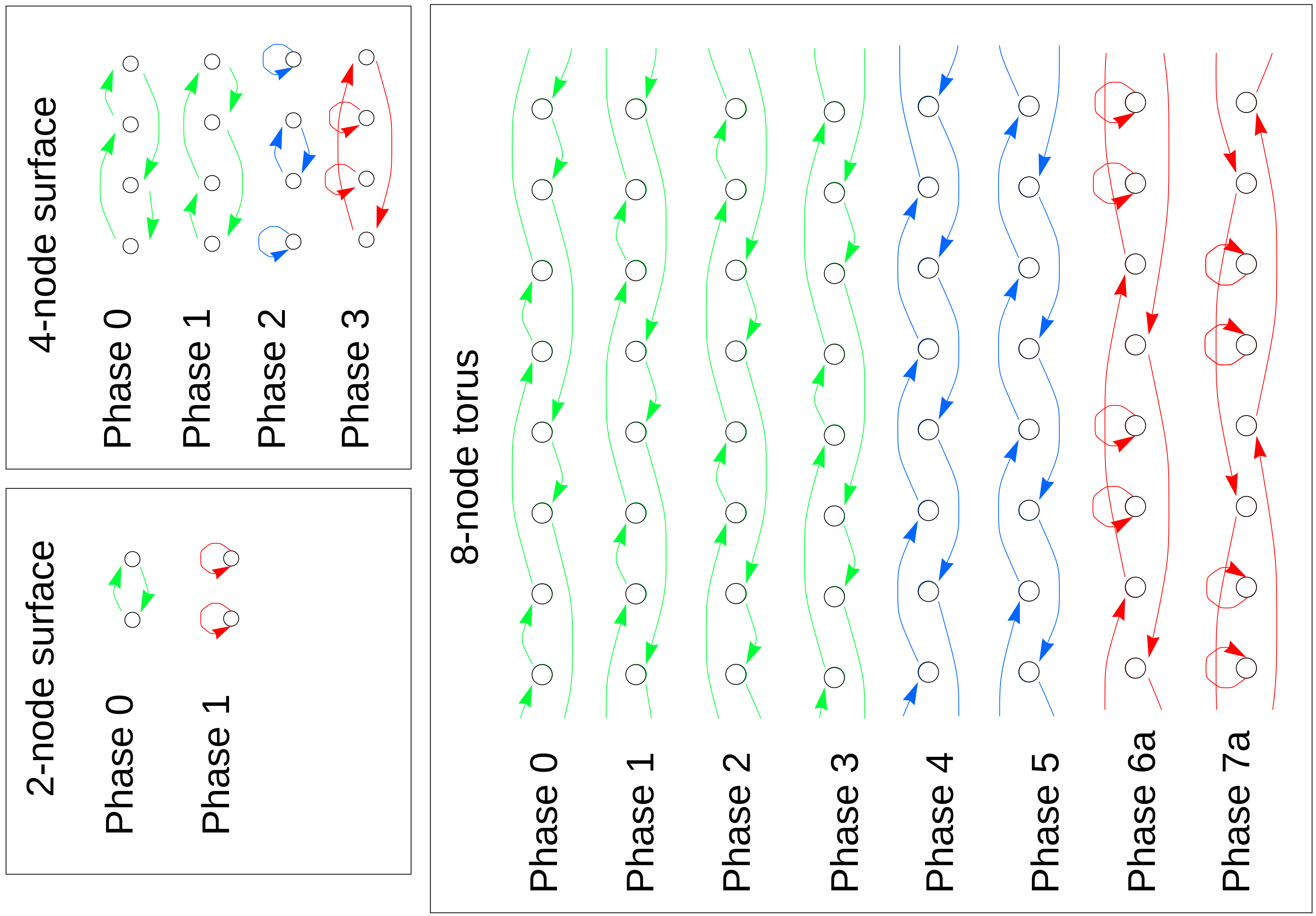
  Bucket work: steps 2,3,4
  Key work: steps 1,5,6

Analysis of sample sort:
Future work!

Index counting:
Bucket[Radix(a)]++



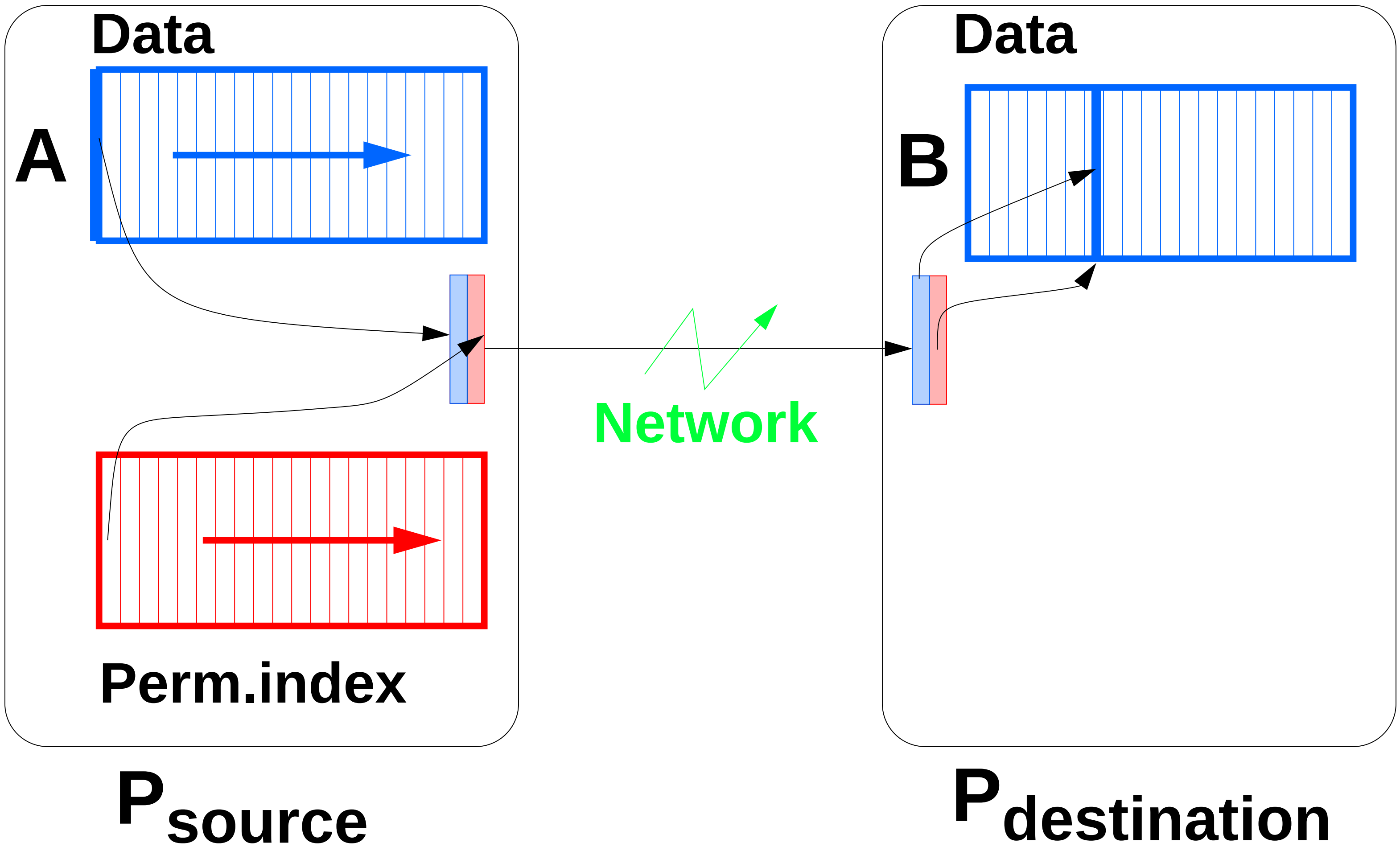
Patterns



Ref: Hinrichs et al. SPAA94

Grouped Permutation (B=Perm*[A])

(prearranged for a message passing machine)



AAPC: Algorithm - Router Interaction