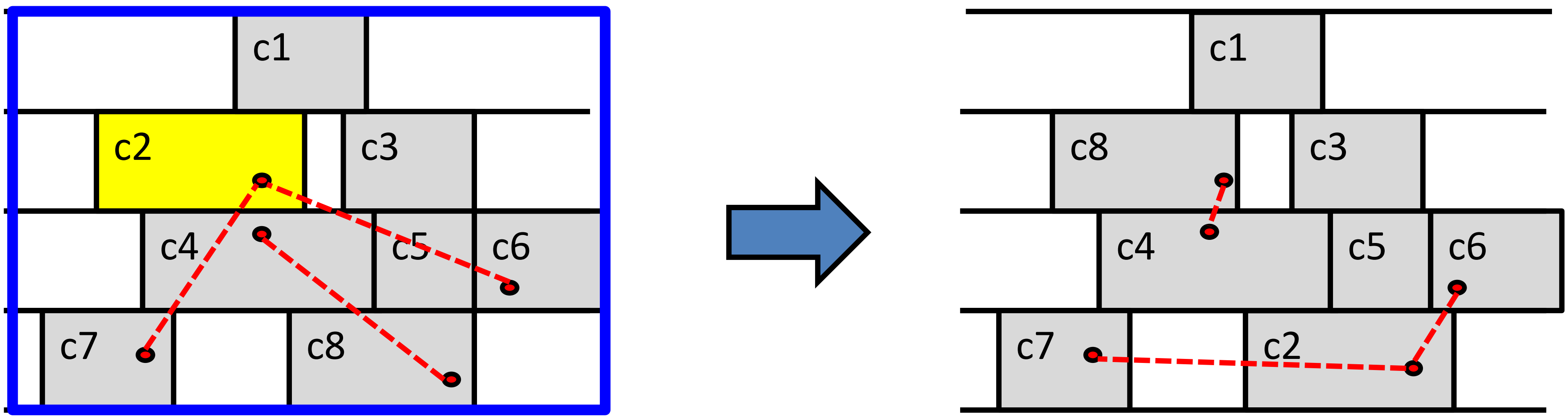
Detailed Placement

- Given a legalized placement solution, detailed placement further improves the wirelength (or other objectives) by locally rearranging cells while maintaining legality.
- Room for wirelength improvement?
  - A global placement algorithm typically uses an inaccurate wirelength model
  - A global placement algorithm might place a cell in a subregion without paying attention to the location of the cell within the subregion
  - During legalization, wirelength is likely to be worsened

Detailed Placement Techniques (1/5)

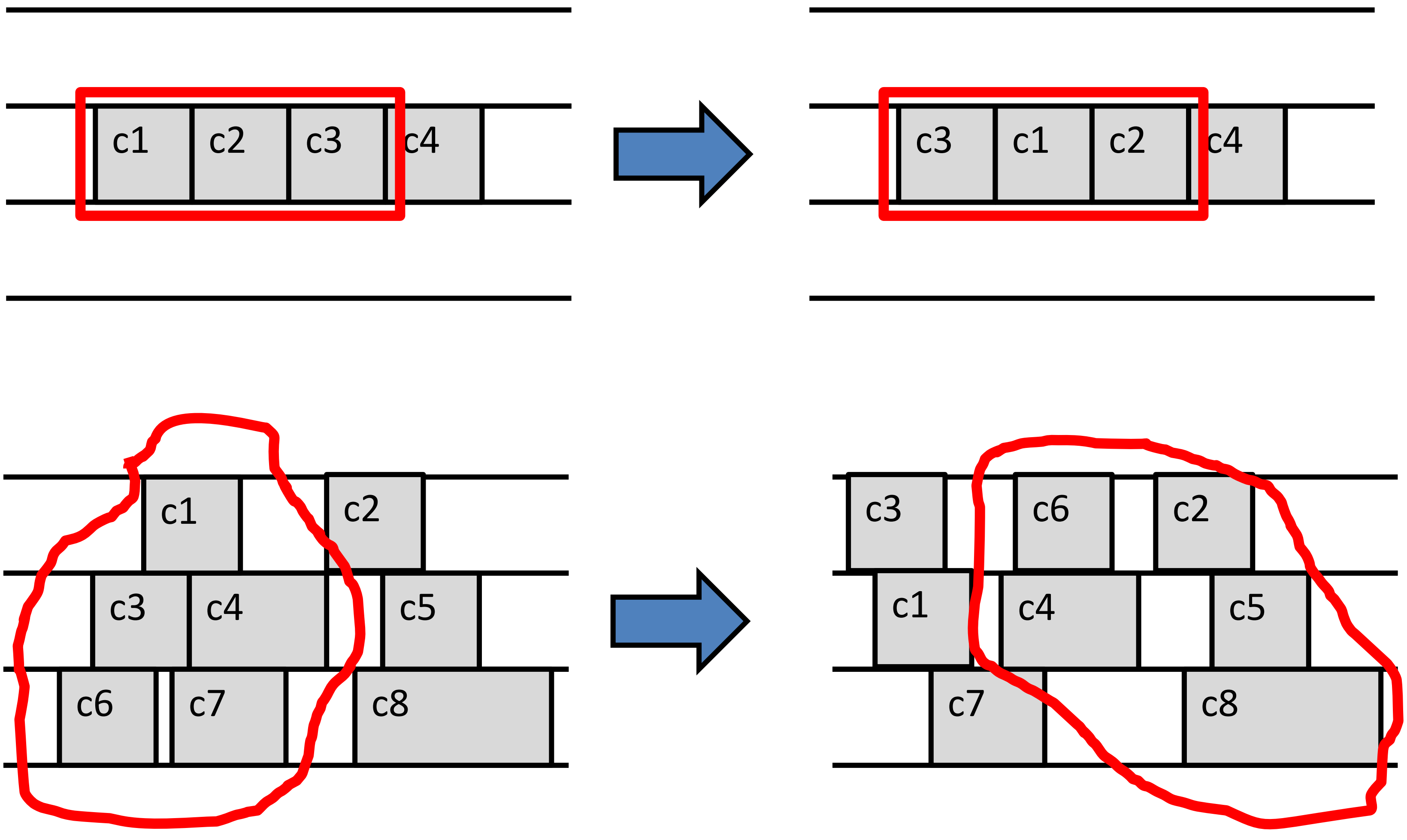
- Moving cells to minimize total HPWL without cell overlapping

Cell Swapping



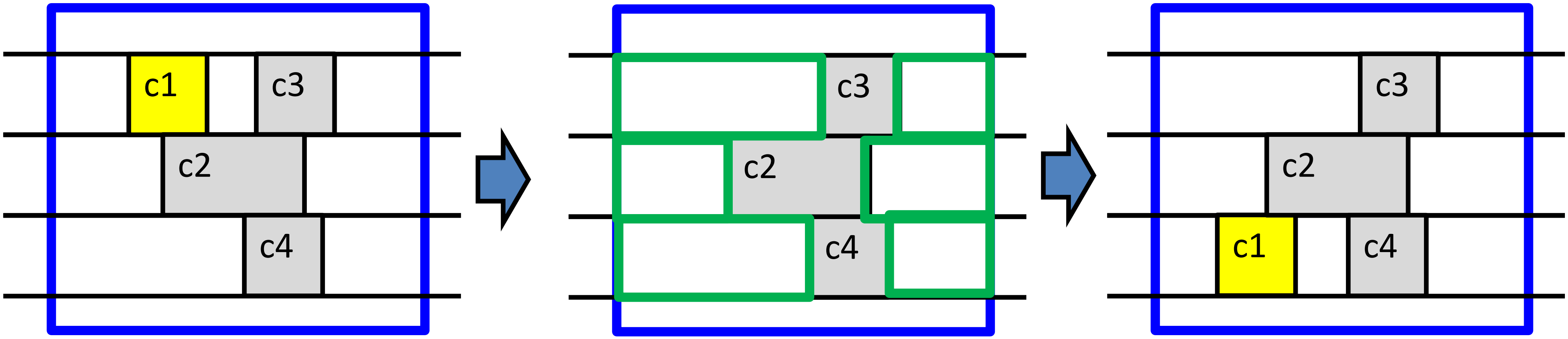
Detailed Placement Techniques (2/5)

Sliding Windows (followed by Branch and Bound or Network Flow)

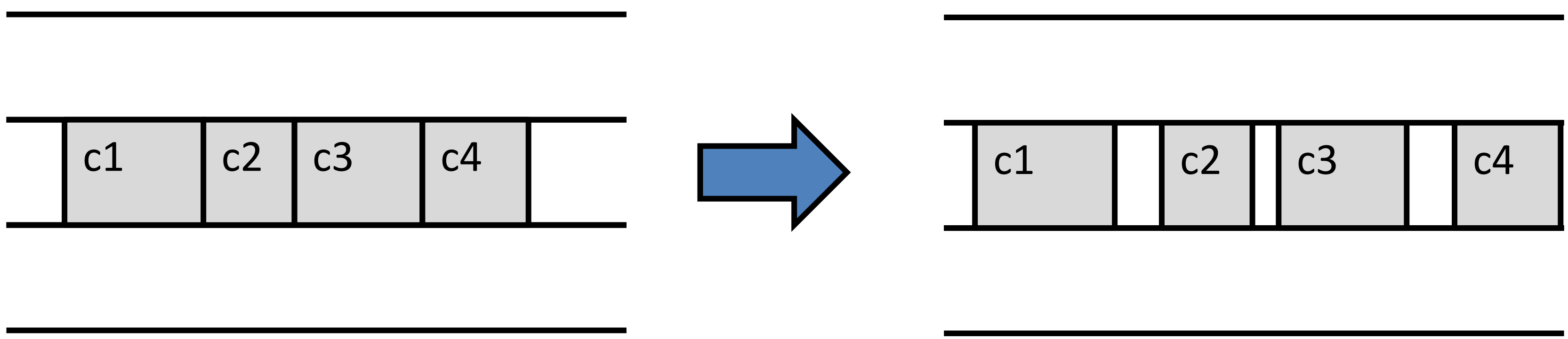


Detailed Placement Techniques (3/5)

Moving Cells to Empty Spots

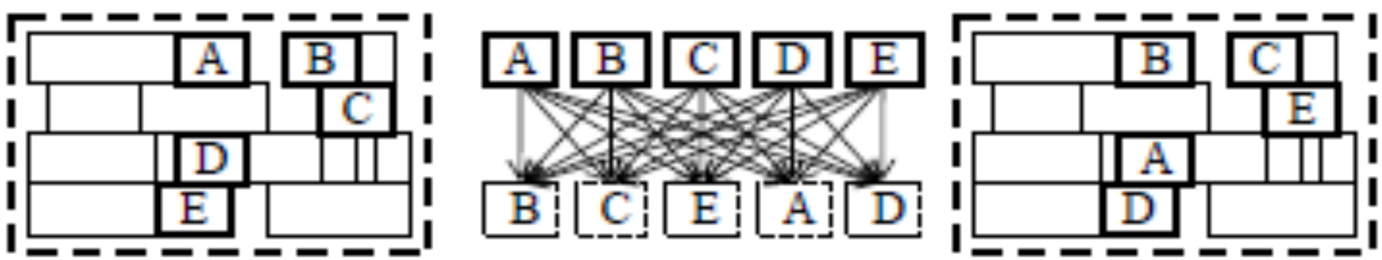


Dynamic-Programming-based Single-Row Placement



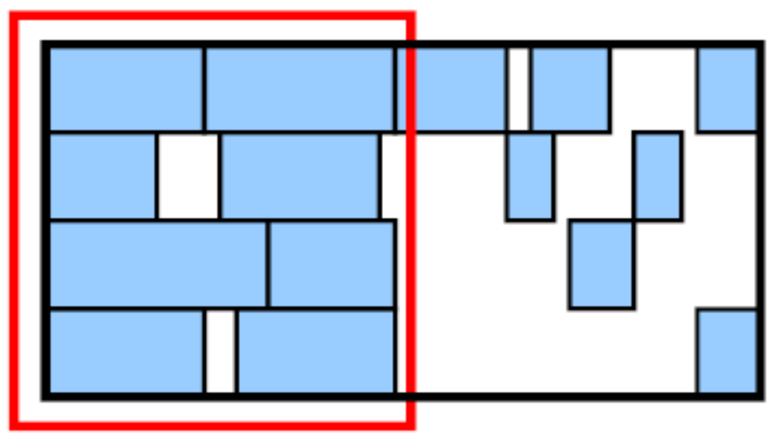
Detailed Placement Techniques (4/5)

- Cell matching
  - Select a window
  - Select **independent** cells (i.e., no common net between any pair of cells) from the window
  - Create a bipartite matching problem (edge weight = wirelength)
  - Find the minimum weighted matching to optimize the wirelengt
  - Update cell positions



Detailed Placement Techniques (5/5)

- Cell sliding: density optimization
- Steps
  - Select an overflow window
  - Calculate the amount of area to shift
  - Move cells left/right to reduce the density

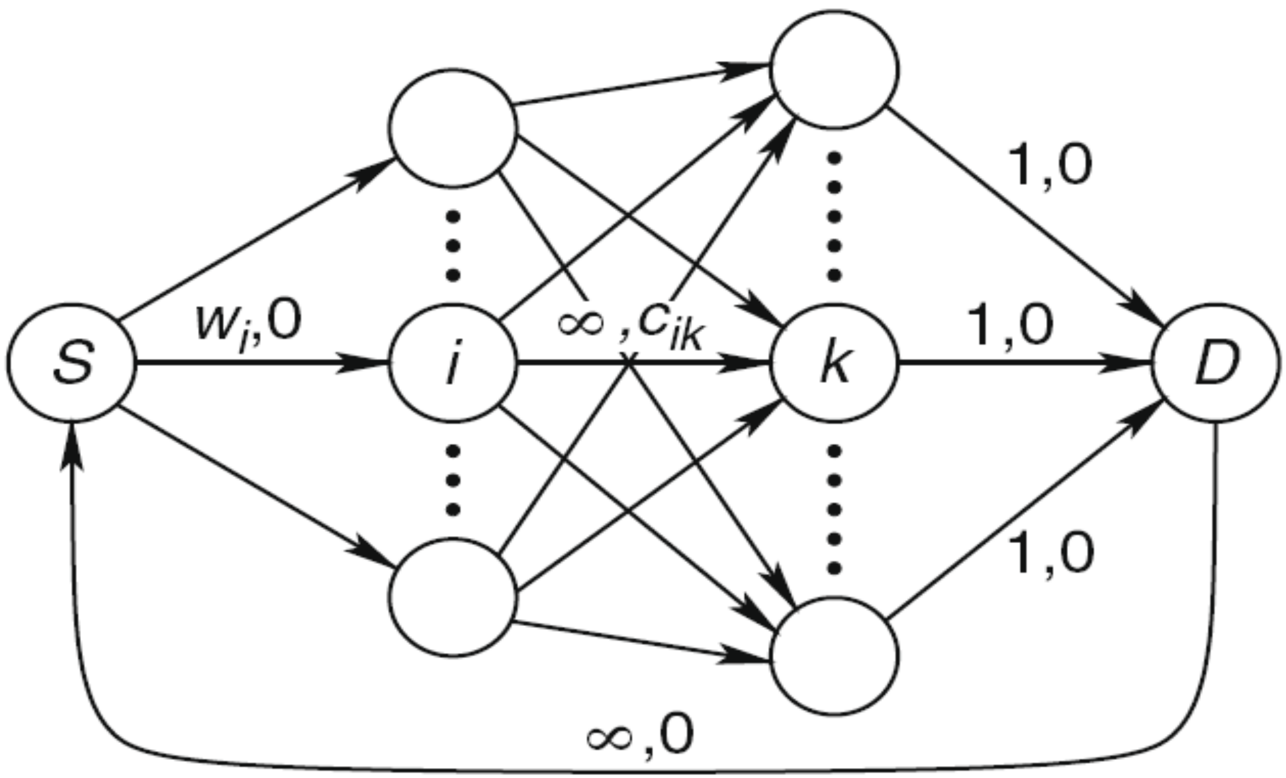


Detailed Placement: Domino [IEEE TCAD-94]

- Use a sliding window approach to iteratively refine a small region
- The problem of cell assignment is formulated as a transportation problem
- Each cell is divided into unit-width subcells
- The problem of transporting the subcells to the placement slots that minimizes WL is transformed into a **minimum cost maximum flow** problem

Min Cost Max Flow Problem

- c_{ik} models the total HPWL of nets connected to cell i if a subcell of i is assigned to location k
  - Estimated by analyzing different cases



Cost Calculation

- e: a net connected to cell i
- e_i: the set of cells connected to net e inside the region.
- Three cases
  - $|e_i| = 1$: The only cell inside the region that net e connects to is cell i. The HPWL of net e can be calculated exactly.
  - $1 < |e_i| < |e|$: Net e connects cells other than cell i both inside and outside the region. The unknown locations of cells in e_i - $\{i\}$ are estimated by their coordinates in the current placement. Then the HPWL of net e can be calculated.
  - $|e_i| = |e|$: Net e connects only to cells inside the region. The locations of cells in e_i - $\{i\}$ are estimated by their coordinates in the current placement. Besides, a virtual cell is introduced at the center of gravity of the cells in e with respect to the current placement. The HPWL of all cells in e together with the virtual cell is calculated and used.

Cell Arrangement

- After solving the network flow problem, subcells are assigned to locations.
- For all subcells of each cell, as they are associated with the same transportation cost and are pulled towards the cheapest location, they tend to lie side by side.
- Each cell is placed in the row holding most of its subcells, and the x-coordinate of the cell is determined by the center of gravity of its subcells.
- The cells in each row of the region are packed according to their x-coordinates to prevent overlap.

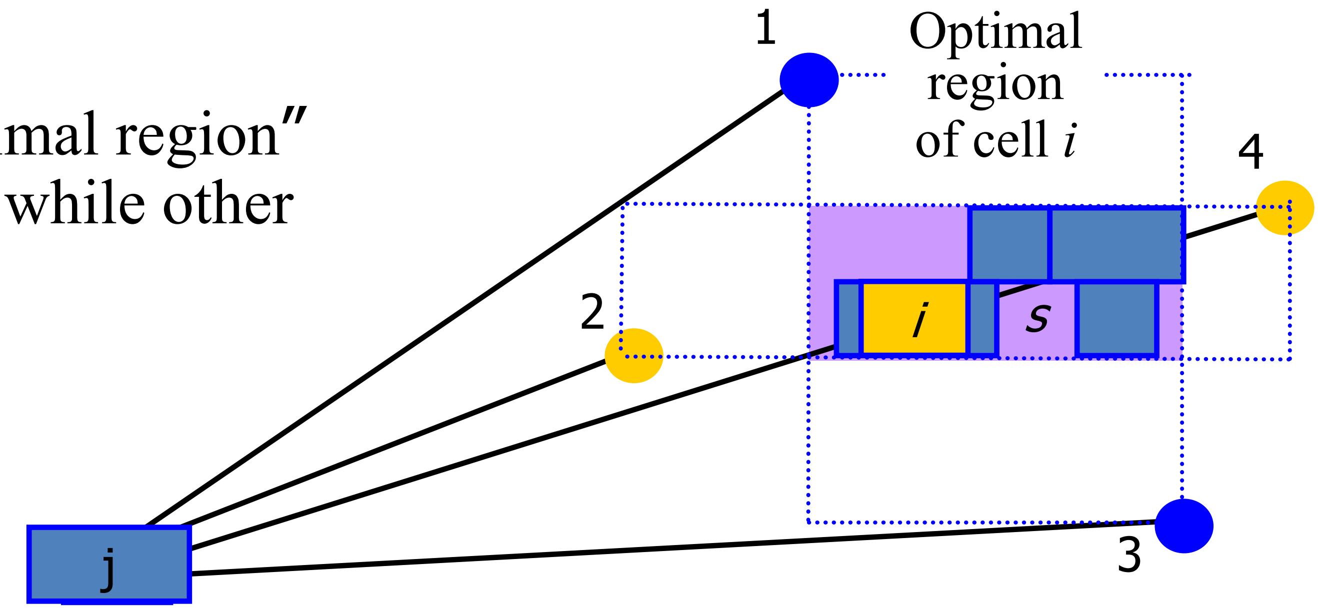
Detailed Placement: FastDP [ICCAD-05]

- A very fast and high-quality greedy heuristic

1. Perform single-segment clustering
2. Repeat
3.   Perform global swap
4.   Perform vertical swap
5.   Perform local reordering
6. Until no significant improvement in wirelength
7. Repeat
8.   Perform single-segment clustering
9. Until no significant improvement in wirelength

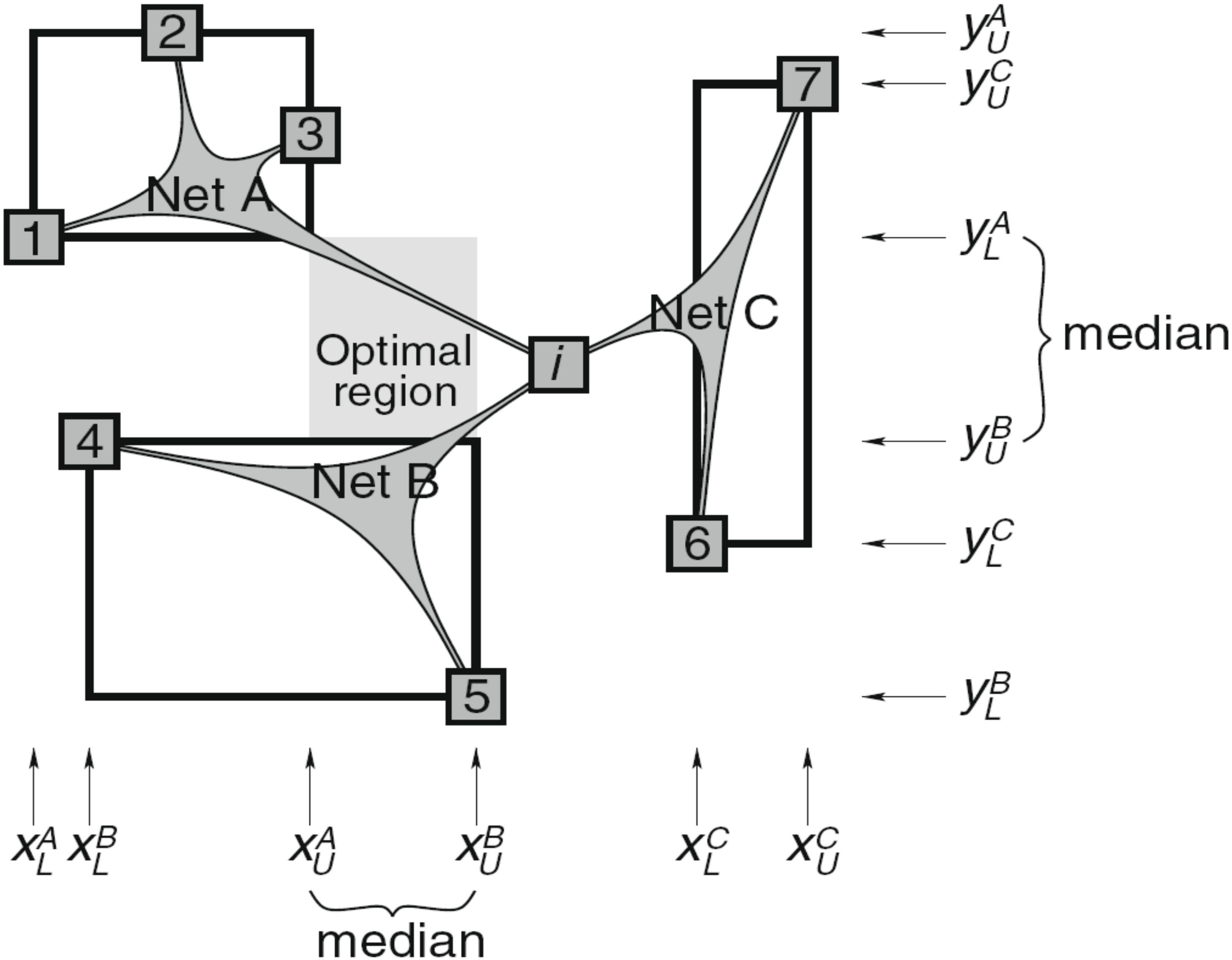
Global Swap

- **Main idea:**
  Move a cell to its "optimal region" (HPWL is minimized) while other cells are fixed



- **Major steps:**
  - For each standard cell *i*, find its optimal region
  - For every candidate cell *j* in the optimal region of cell *i*, compute the benefit to swap *i* with *j*
  - For every candidate space *s* in the optimal region of cell *i*, compute the benefit to swap *i* with *s*
  - Pick the cell or space with best positive benefit to perform swap

Optimal Region of a Cell [IEEE CAS-81]



Other Techniques in FastDP

- **Vertical swap:**
  - Move a cell one row up or down toward its optimal region to reduce the wirelength.
- **Local reordering:**
  - To fix local errors by reordering 3 adjacent cells
- **Single segment clustering:**
  - Optimally shift cells in a segment (i.e., a maximal unbroken section of a row) to minimize HPWL in linear time

Survey Papers on Placement

- Y.-W. Chang, Z.-W. Jiang, and T.-C. Chen, “Essential Issues in Analytical Placement Algorithms”, IPSJ Trans. on Systems LSI Design Methodology, 2009.

- I. Markov, J. Hu, and M.-C. Kim, “Progress and Challenges in VLSI Placement Research”, Proceedings of the IEEE, 2015.