Checkerboard Switch Block Topologies for Routing Diversity

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Switch Block Background

Three switch block types...

1. disjoint (Xilinx)
   - has structure, easy to layout
   - simple: net on track \( t \) always stays on track \( t \)
2. universal
   - has structure, easy to layout
   - routable: isolated switch blocks can route any valid set of 2-point nets
3. Wilton
   - no structure? hard to layout?
   - most routable: net on track \( t \) changes to track \( t+1 \) or \( W-t-1 \) during a turn
   - call this diversity

Comments:
4. all have similar area per track
5. Wilton requires fewest tracks
6. how to increase diversity?
7. is diversity good?
How to work with long wire segments?

From most flexible to least flexible:

1. traditional (Brown/Rose)
   - in general, may lead to difficult layout structures?
   - too flexible
2. crossing locations
   - better layout structure?
3. midpoint/endpoint segregation
   - midpoint connections separate from endpoints
   - no extra connections on endpoints, saves area
   - suggested by Imran
4. track group segregation (new model)
   - wires with same start, end points form a group
   - easier mathematical analysis later
   - includes Imran switch block
   - used here

**Track group segregation model** used here.
Switch Block Midpoints

Consider two switch blocks, both with same (disjoint) endpoint pattern:

1. midpoint switch blocks with no diversity
   - same midpoint pattern everywhere
   - track t connects to track t
   - different global routes reach same track

2. midpoint switch blocks with diversity
   - same midpoint pattern everywhere
   - track t connects to track t+1
   - different global routes reach different track
   - example: reaches 3 different tracks
   - note: can also use different midpoint pattern along length of wire (see next slide)
Checkerboard Patterns

Additional diversity can be obtained using two switch block layout tiles.
Commutative Switch Blocks

- Commutative switch blocks
  - turn order is not important
  - a state diagram can be used to represent a sequence of turns
  - easier mathematical analysis

- Non-commutative

- Commutative

must check each switch block:
- Wilton switch block **not** commutative
- disjoint is commutative
- new switch block **shifty** similar to Wilton, is designed to be commutative
- **shifty** performance equivalent to Wilton
Commutative Design Framework (CDF)

1. any two-point net may take a complex, arbitrary path
2. a path is represented by a sequence of turns
3. each turn is a permutation (mapping) function, from track t to track f(t)
4. if commutative, the turn sequence can be rewritten in any order
5. choose one order corresponding to a canonical form
6. numerous complex, arbitrary paths are reduced to same canonical expression
7. but different canonical expressions represent different paths to same destination
   ○ choose permutation functions to make canonical expressions diverse,
     i.e. reach different tracks
Checkerboard, Commutative Design Framework
Switch Block Design Problem

Given:
- length 4 wires + checkerboard = 8x8 grid

Consider all possible two-turn paths:
- 8 choose 2 = 28 pairs of paths to same output
- 7 possible output rows
- 6 types of two-point turns
- 6 x 7 x 28 = 1176 pairs of canonical expressions
- note: without checkerboard, only 6 x 3 x 6 = 108 pairs
- more pairs => greater diversity potential

Find:
- mapping functions $f, g$ for two switch blocks

Goal:
- choose $f, g$ for maximum diversity, such that each pair of canonical expressions maps to a different track
Checkerboard, Commutative Design Framework Solution

Wrote equation solver for CDF design problem.

- cannot always find perfect solution
- e.g., small channel width often maps to same track

Sample solution on right for channel width 20 (track group width 5).

Note the solution is very diverse.
CDF Solution: Diversity Results

Design f, g switch blocks for each track group width.

Plot diversity versus track group width.

Maximum diversity = 1176 (no pairs reach same track).