Checkerboard Switch Block Topologies for Routing Diversity

by **Guy Lemieux**
and **David Lewis**

University of Toronto

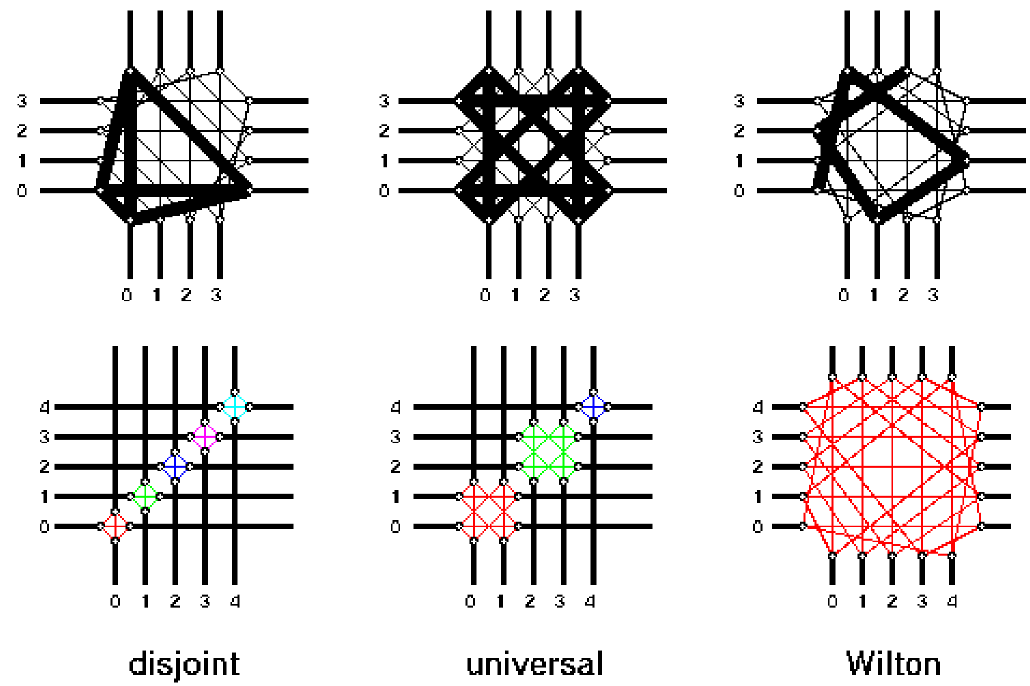
Switch Block Background

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?**



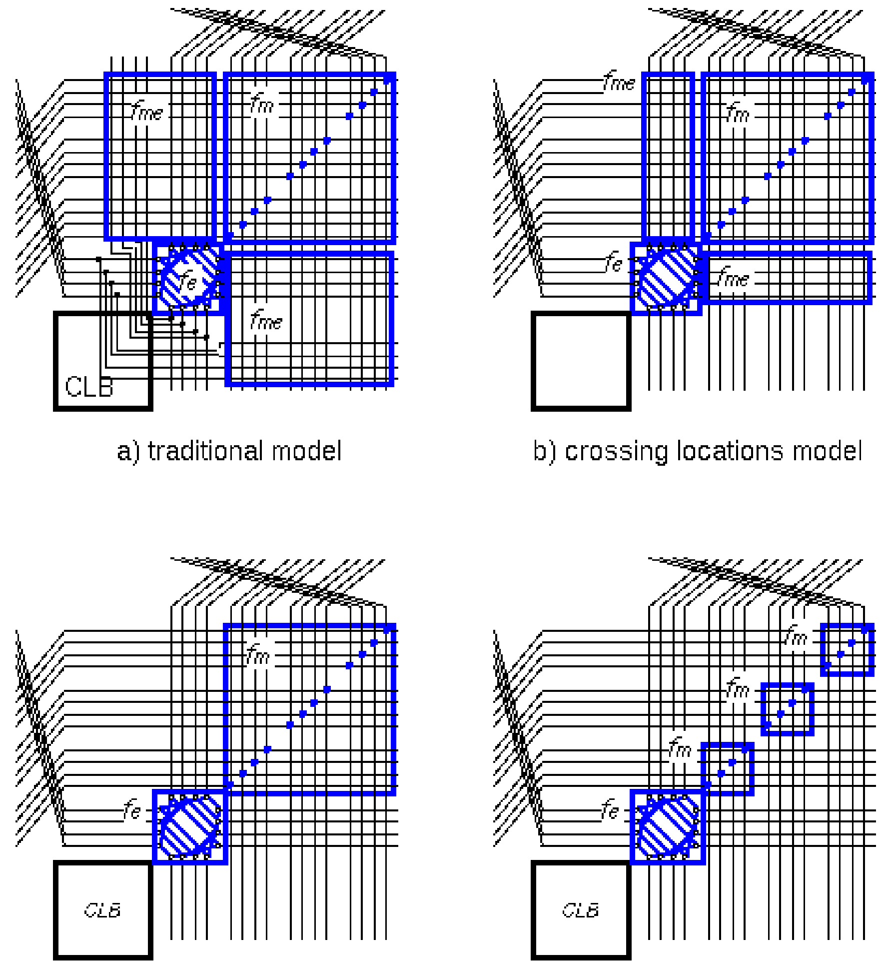
Switch Block Models

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.



a) traditional model

b) crossing locations model

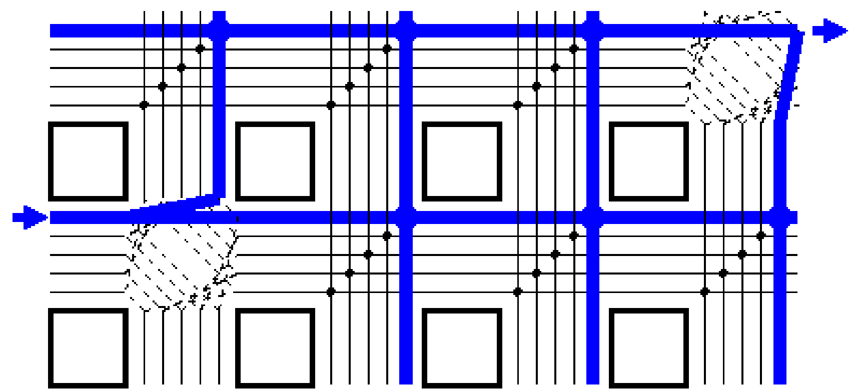
c) midpoint/endpoint segregation model

d) track group segregation model

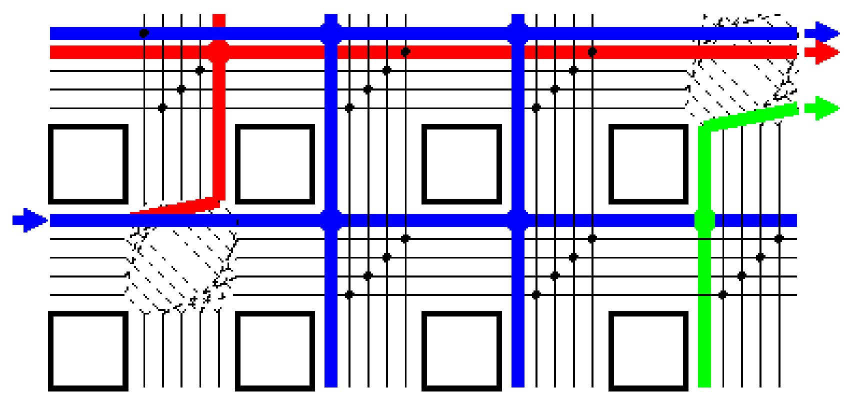
Switch Block Midpoints

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

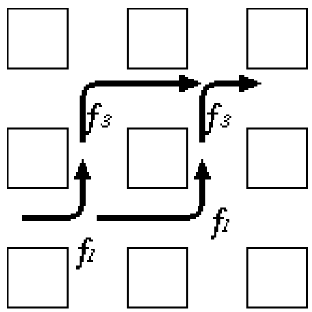


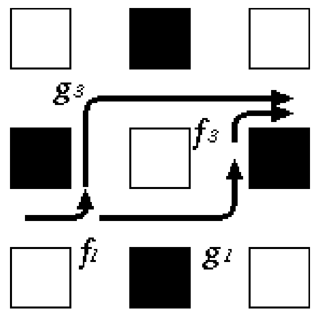
2. midpoint switch blocks with **diversity**
   - same midpoint pattern everywhere
   - track t connects to track t+1
   - different global routes reach **different** track
   - example: reaches 3 different tracks
   - note: can also use **different** midpoint pattern along length of wire (see next slide)

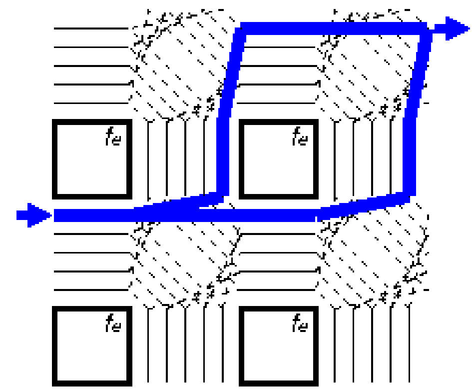


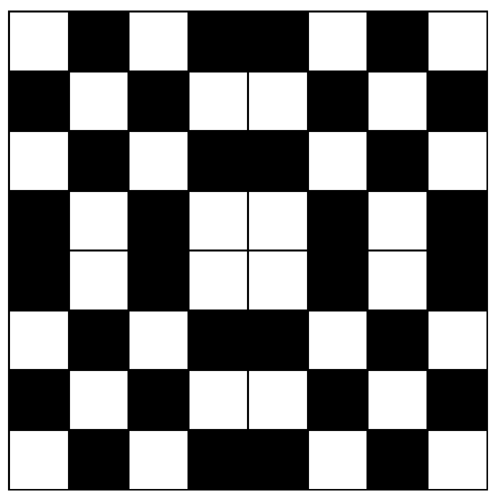
Checkerboard Patterns

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

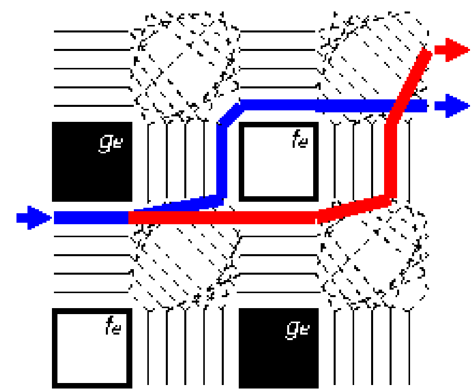




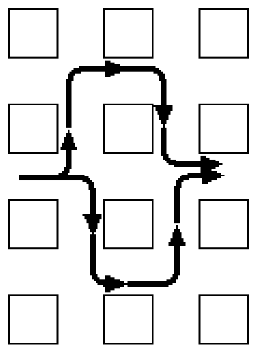


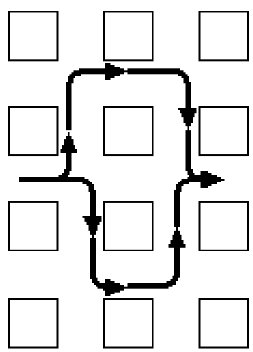


checkerboard
layout pattern,
works with
length 1 and 4
wires

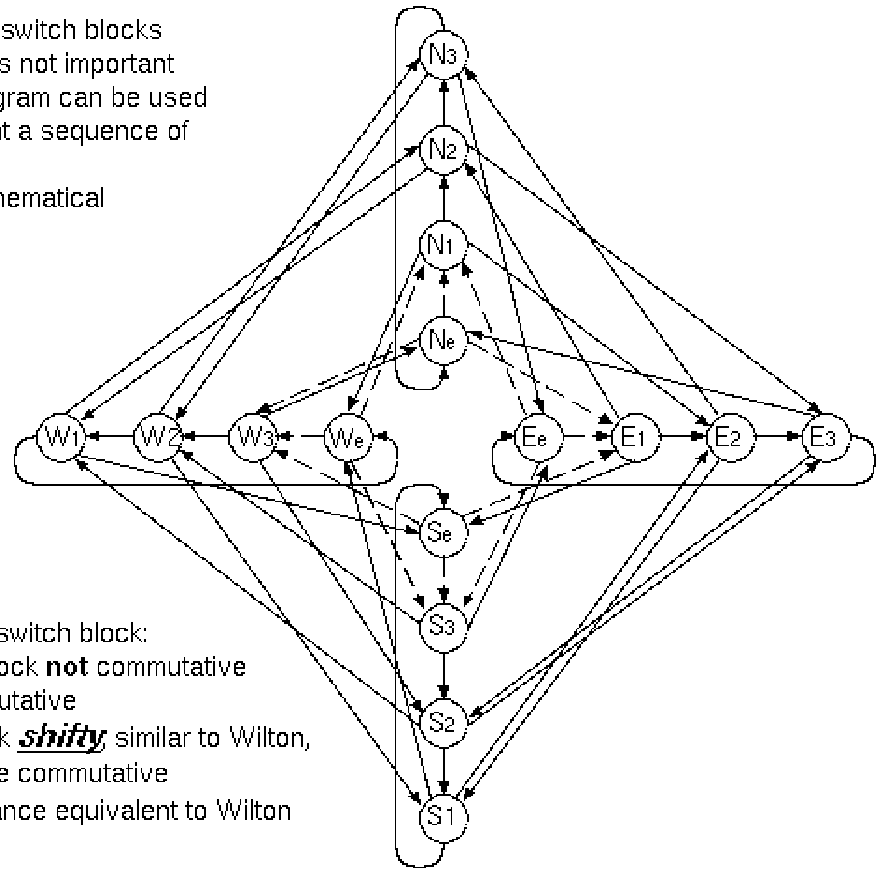


Commutative Switch Blocks


non−commutative


commutative

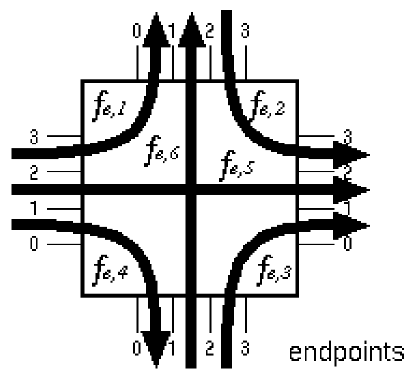
commutative switch blocks
- turn order is not important
- a state diagram can be used to represent a sequence of turns
- easier mathematical analysis

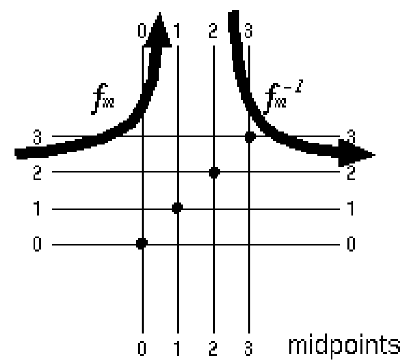


must check each switch block:
- Wilton switch block **not** commutative
- disjoint is commutative
- new switch block ***shifty***, similar to Wilton, is designed to be commutative
- ***shifty*** performance equivalent to Wilton

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:

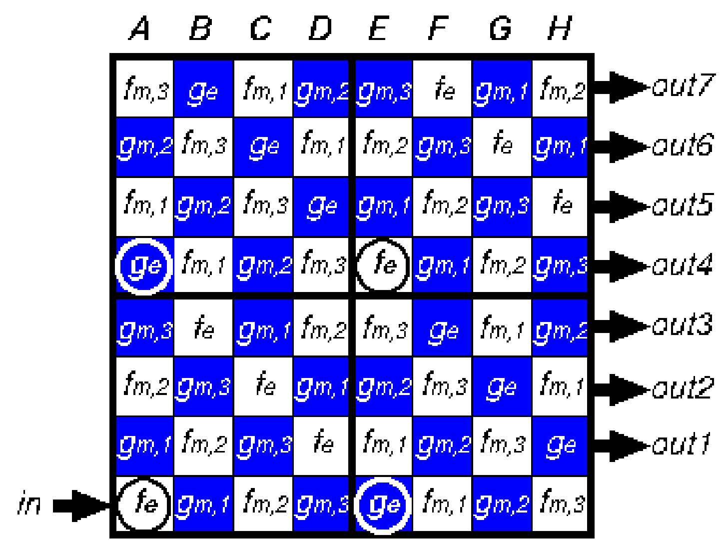
- 8 choose 2 = 28 pairs of paths to same output
- 7 possible output rows
- 6 types of two-point turns
- 6 x 7 x 28 = 1176 pairs of **canonical expressions**
- note: without checkerboard, only 6 x 3 x 6 = 108 pairs
  more pairs => greater diversity potential

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

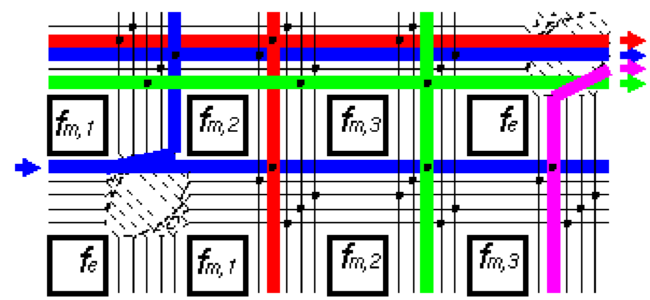
Wrote equation solver for CDF design problem.

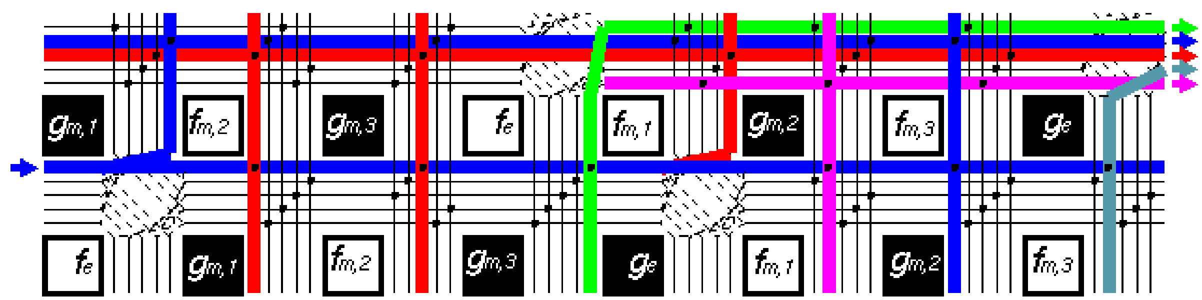
- cannot always find perfect solution
- e.g, small channel width often maps to same track

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

Note the solution is very diverse.

Regular Layout





Checkerboard Layout

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).