Wire segments experiment

Intro

All the wires in a tile belong to one of 3 wires (Fig. 1):

1) Normal case - a wire segment that terminates in the SB. This includes outputs from PE
2) SB output - a wire that originates at this tile. It's driven by one of the mux-es in SB
3) Pass through - a wire that is driven by other tile and goes through this tile. It can also drive inputs to the SB muxes

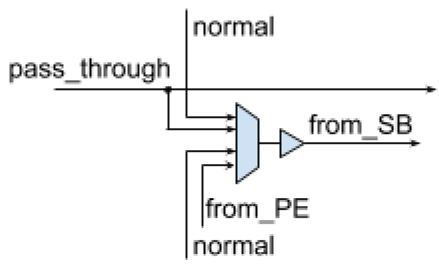

Figure 1: 3 types of wires in SB

The third case only happens if architecture has wire segments that are longer that 1 tile.

The advantage of longer wire segments is that they don't need a driver (or multiplexer) in every tile, thus saving SB area and reducing propagation delay. On the other hand, they can cause "stabs" - a case when a signal terminates in a particular tile, but is still driven out because it can on a wire segment that passes through the tile. This can lead to more tracks required to route a design and a larger routing area.

Each wire in VLSI originates at a driver(or buffer); the area or this driver depends on a load, which in turn depends on a wire segment's length. As the wire segments length increases, the driver's area grows and at some point it becomes cheaper to insert another driver - repeater. So there is a natural limit to the maximum.

In general, it seems logical that the number of track should be a good indicator for the routing area and it is in fact the case but only when we fix the architecture and look at different applications. If we allow the architecture, especially routing to change, this intuition doesn't work. To see why, let's look at the simplest case - wire segments of 1. Obviously this should result in the minimal number of tracks, but it will not give us the minimum area unless the average length of connection (a wire between PEs) is small - close to 1.

Experiment setup

To find the optimal mix of wire segments, we'll use VPR's *estimate* routing area. It takes into account all 3 cases of wires and estimates the size of SB muxes and the area of wire drivers required.

We limit the maximum segment size at 16 and will only consider powers of 2. We'll try all possible combinations of segment lengths with 10% frequency increments. So for the mix of 1/2/4/8/16 log segments will assign each segment an integer frequency of appearing between 0 and 10, such that the sum of all frequencies is equal to 10. If a segment has frequency of 0, it's omitted. In total we have 1002 possible combinations.

We'll do this experiment for every application and will allow VPR to find the smallest number of tracks required to route each applications.

To find the best configuration across all the applications, we'll find the the point that minimizes the sum of *relative* routing areas for all the applications. Relative is calculated as a ratio of 'routing area per tile' for a given configuration over minimal value of this parameter across all configurations.

This method will find a good combination of wire segments across benchmarks. However the resulting mix might not be optimal because the applications have vastly different complexity and thus require different number of tracks. Under this conditions it possible that the best combination is set by the largest application

Results

VPR reports a number of parameters that can be used to evaluate routing:

1) "Routing area per tile" - VPR's estimate of area used for routing in each tile (SB+CB). Units are MTW^2 (minimum transistor width) where 1 MTW = 60λ, λ = 40nm
2) "Average net length" - 1 "unit" equal the length of a tile, same as segment of 1
3) "Average bents" - number of time a signal goes through a mux in the SB, either to change direction or to increase the length
4) "Tracks" - number of tracks entering or leaving a tile in each direction, includes both "passthrough" and "from_sb"(or"normal") types of tracks

The results for each application are summarised in [Tab. 1] and [Tab.2]

App	Routing area per tile	Avg. net length	Avg. bents	Tracks

harris	707.634 - 2574.85	2.61029 - 5.68382	1.49265 - 3.23529	6 - 38
fast	860.409 - 3085.06	3.20645 - 7.91613	2.02366 - 4.0	8 - 34
isp	897.087 - 2508.13	3.16106 - 7.10398	1.91539 - 3.28746	8 - 32
fcam	1332.18 - 2650.09	3.45959 - 10.3116	2.28424 - 3.97345	14 - 40
stereo_med	1305.11 - 2638.87	3.40565 - 13.2177	2.26113 - 4.71731	12 - 38

Table1: Range of observed parameters

App	Segments, best	Tracks, best	avg. length	avg. bents
harris	0/8/1/0/1 0/9/1/0/0 1/9/0/0/0	6	4.49265 4.30882 4.01471	2.72794 2.70588 2.48529
fast	0/7/2/0/1 0/7/2/1/0 0/8/2/0/0	8	4.84946 4.83226 5.16129	2.89032 2.89677 3.12043
isp	0/9/0/1/0 1/9/0/0/0	8	4.60143 4.39755	2.50255 2.29154
fcam	0/1/6/2/1 0/1/7/1/1	16	4.61650 4.55512	2.82736 2.82296
stereo_med	0/5/0/2/3	14	6.23463	3.78127

Table2: Parameters for combination of segments that archives smallest area

The combination of segments is reported as a repetition frequency for each segment starting from length 1. For example, “0/5/0/2/3” means 0% of length 1, 50% of length 2, 0% of length 4, 20% of length 8 and 30% of length 16

The best combination of segments archives the minimum sum of relative routing area is:

0/1/8/0/1

The value of minimum sum is ~5.86. The routing results for this combination are summarized in Tab 3

App	Routing area per tile	Relative to max	Tracks	avg. length	avg. bents
harris	794.819	0.30868555	8	3.41176	2.18382
fast	937.007	0.30372408	10	3.91613	2.50538
isp	926.563	0.36942383	10	3.85015	2.45158
fcam	1504.29	0.56763733	18	4.49188	2.5793
stereo_med	1352.69	0.51260198	16	5.2258	3.18233

Table3: Parameters for 0/1/8/0/1 - “best” combination of segments

To visualize the 5-d function of results, we project the input coordinates to 1-d by calculating the “average wire segments length” = the sum of ‘segment length’*’frequency’. The result is not a function because for some point we have multiple possible combinations (see Fig 2 for example).

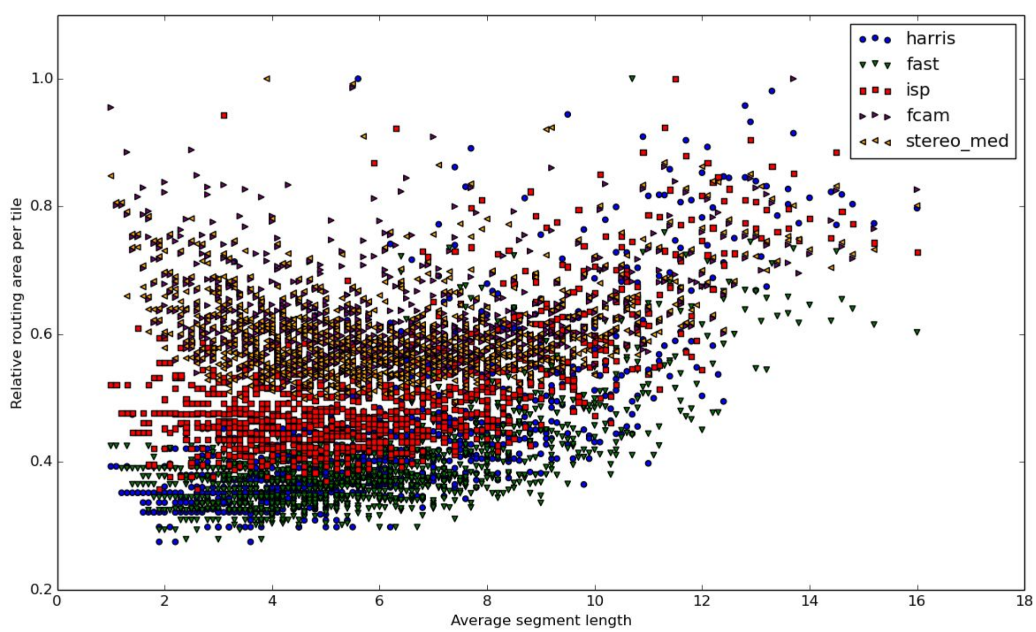

Figure 2: Relative routing area vs average segment length

Fig 3 uses the same data as Fig 2 but shows the front (minimal value at each average) - solid line, Pareto front - dashed line, “x” mark the best for each application (also shown are all other possibilities for that average), “start” shows values for 0/1/8/0/1 - the “best” segment combination. As we see, this point is mostly influenced by ‘fcam’, however the values for other applications are not too far from respective minimums.

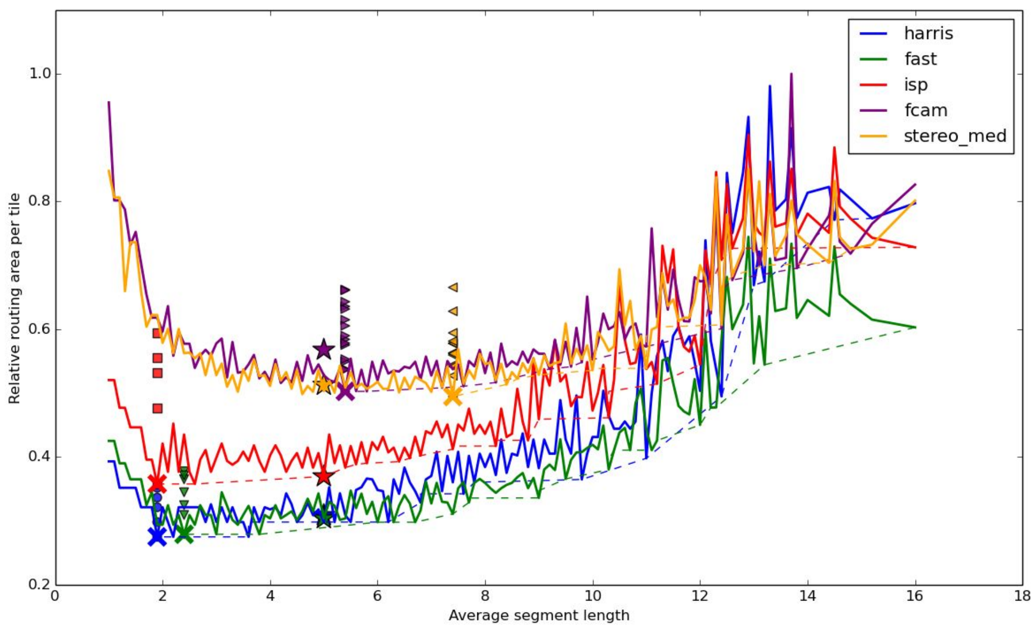

Figure 2: Relative routing area vs average segment length - front and Pareto