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A Note on the Three-Dimensional Single-Active-Layer Routing

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1 Introduction

The 3-D channel is a 3-D grid G consisting of columns, rows, and layers which are planes defined by fixing x-, y-, and z-coordinates, respectively. The numbers of columns, rows, and layers are called the width, depth, and height of G, respectively. G is called a (W, D, H)-channel if the width is W, depth is D, and height is H. A vertex of G is a grid point with integer coodinates. We assume without loss of generality that the vertex set of a (W, D, H)-channel is $\{(x, y, z)|x \in [W], y \in [D], z \in [H]\}$, where $[n] = \{1, 2, \ldots, n\}$ for a positive integer n. Layers defined by $z = H$ and $z = 1$ are called the top and bottom layers, respectively.(See Fig.1.)

A terminal is a vertex of G located on the top or bottom layer. A net is a set of terminals to be connected. A net containing k terminals is called a k-net. A k-net is called a multiterminal net if $k \geq 2$. A tree connecting the terminals in a net is called a wire. The object of the routing problem is to connect the terminals in each net with a wire using as few layers as possible and as short wire as possible in such a way that wires for distinct nets are vertex-disjoint. In case of the 3-D single-active-layer routing all the terminals are located either on the top or bottom layer. This is a special case of the 3-D channel routing where each terminal is located on the top or bottom layer. A set of nets is said to be routable in G if G has vertex-disjoint trees spanning the nets.

For the 3-D channel routing, it has been known that the problem of deciding if a given set of nets is routable in a 3-D channel is NP-complete [1]. It has been also known that if G is a $(2N, 2N, 3N)$-channel, the terminals are located on vertices with odd x- and y-coordinates, and each net has terminals both on top and bottom layers, then any set of 2-nets is routable in G [2]. Moreover, if G is a $(2N, 2N, N/2-\epsilon)$-channel for any $\epsilon > 0$, the terminals are located on vertices with odd x- and y-coordinates, and each net has terminals both on top and bottom layers, then there exists a set of 2-nets that is not routable in G [2].

For the 3-D single-active-layer routing, it has been known that if G is a $(2N, 2N, 3N)$-channel, and the terminals are located on vertices with odd x- and y-coordinates, then any set of 2-nets is routable in G [3]. It has been also known that if G is a $(2N, 2N, 6N)$-channel, the terminals are located on vertices with odd x- and y-coordinates, then any set of multiterminal nets is routable in G [3]. Moreover if G is a $(2N, 2N, N/4 - \epsilon)$-channel for any $\epsilon > 0$, and the terminals are located on vertices with odd x- and y-coordinates, then there exists a set of 2-nets that is not routable in G [3].

The purpose of this paper is to improve results above as follows.

Theorem 1 *If G is a $(2N, 2N, 5N/2)$-channel, and the terminals are located on vertices with odd x- and y-coordinates either on the top or bottom layer, then any set of multiterminal nets is routable in G.*

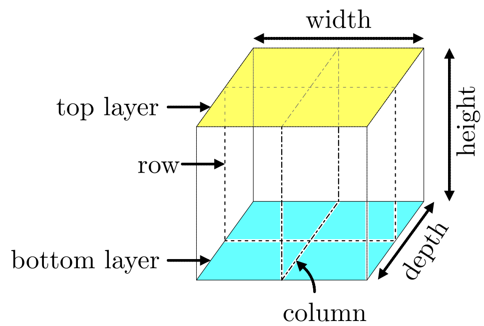

Figure 1: Three-dimensional channel

2 Proof Sketch of Theorem 1

The theorem is proved by showing a polynomial time routing algorithm. The algorithm is a modification of a 3-D channel routing algorithm in [2], and consists of three phases. Each of the first two phases uses N layers, while the last phase uses at most $N/2$ layers.

Let $t_1, t_2, \ldots, t_n$ be the terminals on the top layer. We assume without loss of generality that the terminals in every multiterminal net are consecutive in the sequence. We use virtual terminals $s_1, s_2, \ldots, s_n$ arranged in a snakelike order on the bottom layer such that $s_1, s_2, \ldots, s_N$ are on the same column defined by $x = 1$. We also use virtual 2-nets $\{t_1, s_1\}, \{t_2, s_2\}, \ldots, \{t_n, s_n\}$.

We apply the first two phases of 3-D channel routing algorithm in [2] for the virtual 2-nets using $2N$ layers. Then we can prove from the arrangement of the virtual terminals that the terminals of every original multiterminal net can be connected by using at most $N/2$ more layers.

References

[1] S. Tayu and S. Ueno, "The Complexity of Three-Dimensional Channnel Routing," IEICE Technical Report, Vol. 106, No. 366, pp. 37–41, 2006.

[2] S. Tayu, P. Hurtig, Y. Horikawa, and S. Ueno, "On the Three-Dimensional Channel Routing," Proceedings of the IEEE International Symposium on Circuits and Systems, pp.180–183, 2005.

[3] A. Recski and D. Szeszlèr, "Routing vertex disjoint Steiner-trees in a cubic grid and connections to VLSI," Discrete Applied Mathematics, pp.44–52, 2007.