

# VLSI Circuit Partitioning

**ESE 556 VLSI Physical and Logic Design Automation**

## **Abstract**

To implement and experiment the Fiduccia-Mattheyses partitioning algorithm implemented for gate-level designs

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## **1. Problem Statement:**

The main aim of the project is to implement and experiment the Fiduccia-Mattheyses partitioning algorithm implemented for gate-level designs and to this minimize the cut-set size while meeting the given area constraints.

## **2. Introduction:**

### **2.1. Need for Partitioning**

As the data sets become more and more complex and vast, the decomposition of the sets becomes necessary. Here, the need of partitioning the data set arises. Partitioning of data into smaller sets helps define the structure in a more modular way. It does not alter the basic functionality of the structure, but gives a more simplistic approach to tackle and understand the set better.

Partitioning plays a crucial role in reducing the design complexity of VLSI chips. When the chips contain a multitude of transistors (usually in millions), partitioning the transistor set helps aid the designing process. VLSI partitioning takes place at several levels (system level, board level, chip level) but inputs of the problem remain similar (analogous to the level), and the output desired is always some sub-circuits that are same in functionality to the original set.

### **2.2. Overview of the Problem statement**

When a circuit is partitioned in multiple sub-circuits, often there exists a large number of interconnections between the various sub-circuits. These interconnections between the sub-circuits is called the cut-set and the total number of these interconnections is called the cut-set size. The main objective of the project is to first partition the given set into two subsets, and then minimize the cut-set size while also adhering to the given area constraints. Fiduccia-Mattheyses partitioning algorithm is to be used.

### **Kernighan-Lin Algorithm**

Kernighan-Lin algorithm or simply KL algorithm is a heuristic algorithm to partition graphs into two subsets of equal sizes. An initial partition is made, and the cut-set size for that partition is determined. Then one vertex from each partition is picked and interchanged in the two sets to reduce the gain. This process is repeated until the cut-set size cannot be reduced any further. Choosing the vertex pair depends on which pair gives the maximum benefit when their places are interchanged. KL algorithm forms the basis of our understanding of the Fiduccia-Mattheyses partitioning algorithm.

### **Fiduccia-Mattheyses Algorithm**

Fiduccia-Mattheyses algorithm or FM algorithm is essentially an upgrade to the KL algorithm. Differences between the two are:

1. Instead of moving a pair of nodes across each partition, only one node is moved at a time from one partition to the other. This enables to handle partitions that are not essentially equal in size (when number of nodes are considered) and could also vertex weights (to meet the area constraints)
2. FM algorithm, unlike KL algorithm, is not limited to graphs. Hyper-graphs can also be partitioned.
3. Since only one vertex is chosen to move instead of choosing the best pair of vertex to move, FM algorithm is much faster than KL algorithm.

### 3. Related Work:

Since partitioning of nets is critical in the VLSI industry, a lot of research work is available with respect to improvement of the partitioning [1] [2] using the ratio factor as a criterion or extending it to multiway partitioning [3] from bi-partitioning algorithm which requires the use of efficient data structures for moving the nodes like a LIFO instead of a random queue or FIFO queues. Caldwell, Khang and Markov have proposed Multilevel FM Hypergraph partitioning which exploits the fixed nodes in the partitioning[4]. As directed graphs are used in modeling of data flow in streaming applications the partitioning algorithms can be utilized for parallelizing computation for multiprocessor architectures as proposed recently in the Evolutionary Acyclic Graph Partitioning[5].

### 4. Implementation:

The implementation of the Fiduccia Mattheyses algorithm for minimizing the cut-set size while meeting the area constraints can be split into the following:

#### 4.1. File Parsing:

- Partitioning needs to be done on VLSI networks containing millions of cells and the benchmark for the circuit is provided by [6] THE ISPD98 CIRCUIT BENCHMARK SUITE, where the IBM files .net, .are, .netD files which serve as the input for the partitioning can be obtained.
- Various data like the area of each cell, the name of the cell, the connections to other nodes, source cell information, direction, etc are obtained after parsing these files and the data is populates in two structures which is the bucket structure and the cell structure (cell is called vertex in hypergraps).

#### 4.2. Generation of initial partition:

- The initial bi partition for the given netlist can be obtained either randomly or in a specific way to aid the cut set size reduction.
- If the total area is calculated and the ratio factor is fixed based on this the part A sectioning can be decided. But it is a trade off in time as randomized function can be used to divide the bucket structure into 2 groups.

$$\text{Ratio Factor} = \text{Area A} / (\text{Area A} + \text{Area B})$$

- Area A → Area of the first partition (A)
- Area B → Area of the second partition (B)
- Total Area → Area A + Area B

#### 4.3. Bucket Structure:

- The bucket structure is implemented using a two-dimensional linked list as the number of nodes is dynamic the data of the cell and the network cannot be stored in a static array.

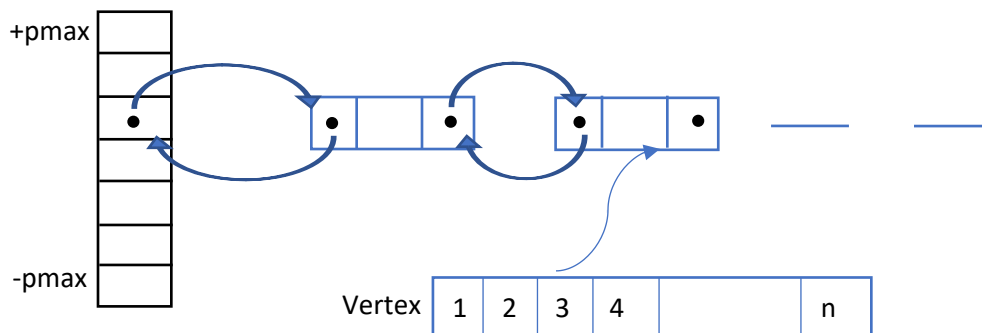


Fig 1.

#### 4.4 Fiduccia Mattheyses:

Implement the FM algorithm:

- Calculate the gain of all the nodes after checking the connections and critical nets using the display cell structure.

$$\Delta g(c) = FS(c) - TE(c)$$

Where the “moving force”  $FS(c)$  is the number of nets connected to  $c$  but not connected to any other cells within  $c$ 's partition, i.e., cut nets that connect only to  $c$ , and the “retention force”  $TE(c)$  is the number of uncut nets connected to  $c$ .

The higher the gain  $\Delta g(c)$ , the higher is the priority to move the cell  $c$  to the other partition.

- Compute the balance criterion for area constraint:

$$[r.area(V) - area_{max}(V)] \leq area(A) \leq [r.area(V) + area_{max}(V)]$$

- Choose the cell with maximum gain and move it to the other partition and fix it.

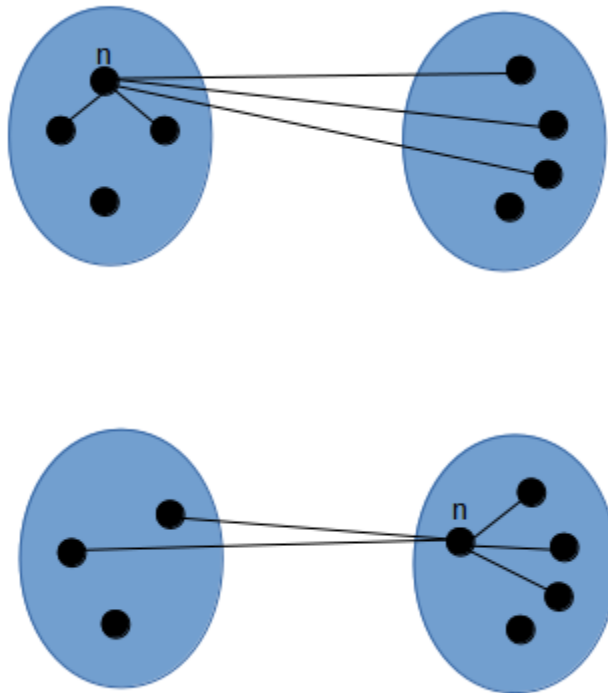
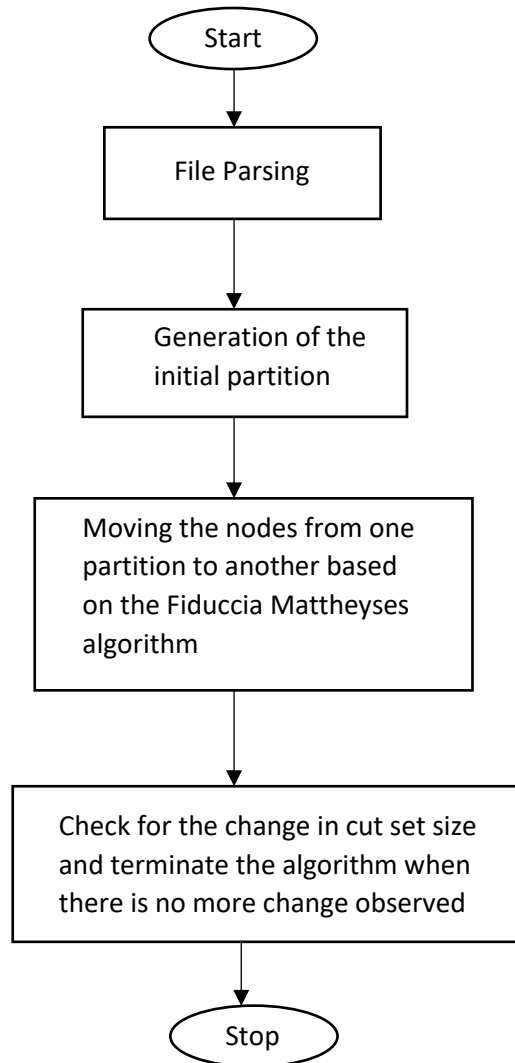


Fig 2.

- Update all the cell that are connected to critical nets via the base cell
- Repeat the previous two steps until all cells are locked or until the minimum cut size with maximum gain is obtained.
- Figure out the best sequence to move all the cells.

#### 4.5. Flowchart:



#### 5. Experimental results:

The Fiduccia Mattheyses algorithm implemented for circuit partitioning was tested for the IBM networks which are provided in the benchmark webpage <http://vlsicad.ucsd.edu/UCLAWeb/cheese/ispd98.html>

The initial cut set size and the final cut set size after the finalized partition are calculated and the percentage reduction is also calculated.

The figures attached show the runtime, reduction in cut set size for all the 13 IBM files and the table shows the percentage reduction.

The screenshot shows the Eclipse IDE with the project 'FM/Fiduccia\_Mattheyses.cpp'. The code is a C++ implementation of the Fiduccia-Mattheyses algorithm. The output terminal shows the execution of 'C:\Sukrutha\FM\FM\_improved.exe'. The output displays a list of node numbers and their corresponding group and area values, followed by a summary of the cut set size and execution time.

```

1240> while (getline (myfile2,line) )=
125> {
126>     string first_letter;
127>     s_count_prev=s_count;
128>     if (line.find("s")!=std::string::npos)=
129>     {
130>         node_flag=1;
131>         s_count++;
132>         offset=line.find("s");
133>         line_substr=line.substr(1,offset-1);
134>         first_letter = line.substr(0,1);
135>         v_pointer->cname=strtol(line_substr.c_str(),
136>                                &first_letter.compare("a")==0)=
137>         {
138>             v_pointer->ap=0;
139>             if (first_letter.compare("p")==0)=
140>             {
141>                 v_pointer->ap=1;
142>             }
143>         }
144>
145>         h_pointer=v_pointer;
146>         display_cell * tempv = (display_cell*)malloc(sizeof(display_cell));
147>         tempv->next = NULL;
148>         v_pointer->next = tempv;
149>         v_pointer->down = (display_cell*)malloc(sizeof(display_cell));
150>         v_pointer=v_pointer->down;
151>     }
152>
153>
154>     if (s_count_prev!=s_count)=
155>     {
156>         node_count=0;
157>     }
158>     else if (node_flag==1)=
159>     {
160>         display_cell * tempv = (display_cell*)malloc(sizeof(display_cell));

```

```

node number.....**225**node group.....**1**node area.....**0
node number.....**226**node group.....**0**node area.....**0
node number.....**227**node group.....**1**node area.....**0
node number.....**228**node group.....**0**node area.....**0
node number.....**229**node group.....**0**node area.....**0
node number.....**230**node group.....**0**node area.....**0
node number.....**231**node group.....**1**node area.....**0
node number.....**232**node group.....**1**node area.....**0
node number.....**233**node group.....**0**node area.....**0
node number.....**234**node group.....**0**node area.....**0
node number.....**235**node group.....**1**node area.....**0
node number.....**236**node group.....**0**node area.....**0
node number.....**237**node group.....**1**node area.....**0
node number.....**238**node group.....**0**node area.....**0
node number.....**239**node group.....**1**node area.....**0
node number.....**240**node group.....**1**node area.....**0
node number.....**241**node group.....**1**node area.....**0
node number.....**242**node group.....**1**node area.....**0
node number.....**243**node group.....**0**node area.....**0
node number.....**244**node group.....**0**node area.....**0
node number.....**245**node group.....**0**node area.....**0
node number.....**246**node group.....**1**node area.....**0
area.....4230016
cut set size.....after.....12191
reduction in cutset size is ...5952
cut set size.....before.....18143

Process returned 0 (0x0)   execution time : 30.500 s
Press any key to continue.

```

Fig 3. Output terminal results for ibm01

The screenshot shows the Eclipse IDE with the project 'FM/Fiduccia\_Mattheyses.cpp'. The code is a C++ implementation of the Fiduccia-Mattheyses algorithm. The output terminal shows the execution of 'C:\Sukrutha\FM\FM\_improved.exe'. The output displays a list of node numbers and their corresponding group and area values, followed by a summary of the cut set size and execution time.

```

1240> while (getline (myfile2,line) )=
125> {
126>     string first_letter;
127>     s_count_prev=s_count;
128>     if (line.find("s")!=std::string::npos)=
129>     {
130>         node_flag=1;
131>         s_count++;
132>         offset=line.find("s");
133>         line_substr=line.substr(1,offset-1);
134>         first_letter = line.substr(0,1);
135>         v_pointer->cname=strtol(line_substr.c_str(),
136>                                &first_letter.compare("a")==0)=
137>         {
138>             v_pointer->ap=0;
139>             if (first_letter.compare("p")==0)=
140>             {
141>                 v_pointer->ap=1;
142>             }
143>         }
144>
145>         h_pointer=v_pointer;
146>         display_cell * tempv = (display_cell*)malloc(sizeof(display_cell));
147>         tempv->next = NULL;
148>         v_pointer->next = tempv;
149>         v_pointer->down = (display_cell*)malloc(sizeof(display_cell));
150>         v_pointer=v_pointer->down;
151>     }
152>
153>
154>     if (s_count_prev!=s_count)=
155>     {
156>         node_count=0;
157>     }
158>     else if (node_flag==1)=
159>     {
160>         display_cell * tempv = (display_cell*)malloc(sizeof(display_cell));

```

```

node number.....**238**node group.....**0**node area.....**0
node number.....**239**node group.....**0**node area.....**0
node number.....**240**node group.....**0**node area.....**0
node number.....**241**node group.....**0**node area.....**0
node number.....**242**node group.....**1**node area.....**0
node number.....**243**node group.....**0**node area.....**0
node number.....**244**node group.....**0**node area.....**0
node number.....**245**node group.....**0**node area.....**0
node number.....**246**node group.....**0**node area.....**0
node number.....**247**node group.....**1**node area.....**0
node number.....**248**node group.....**1**node area.....**0
node number.....**249**node group.....**0**node area.....**0
node number.....**250**node group.....**1**node area.....**0
node number.....**251**node group.....**1**node area.....**0
node number.....**252**node group.....**0**node area.....**0
node number.....**253**node group.....**0**node area.....**0
node number.....**254**node group.....**1**node area.....**0
node number.....**255**node group.....**1**node area.....**0
node number.....**256**node group.....**1**node area.....**0
node number.....**257**node group.....**0**node area.....**0
node number.....**258**node group.....**1**node area.....**0
node number.....**259**node group.....**1**node area.....**0
area.....8458336
cut set size.....after.....22013
reduction in cutset size is ...8555
cut set size.....before.....30568

Process returned 0 (0x0)   execution time : 67.148 s
Press any key to continue.

```

Fig 4. Output terminal results for ibm02

```

C/C++ - FM/Fiduccia_Mattheyses.cpp - Eclipse
File Edit Source Refactor Navigate Search Project Run Window Help

C:\Sukrutha\FM\FM_improved.exe

Fiduccia_Mattheyses.cpp
124 while (getline (myfile2,line) )=
125 {=
126 string first_letter;=
127 s_count_prev=s_count;=
128 if (line.find("s")!=std::string::npos)=
129 {=
130 node_flag=1;=
131 s_count++;=
132 offset=line.find("s");=
133 line_substr=line.substr(1,offset-1);=
134 first_letter = line.substr(0,1);=
135 v_pointer->cname=strtol(line_substr.c_str(),=
136 &first_letter,10);=
137 if (first_letter.compare("a")==0)=
138 {=
139 v_pointer->ap=0;=
140 }=
141 if (first_letter.compare("p")==0)=
142 {=
143 v_pointer->ap=1;=
144 }=
145 h_pointer=v_pointer;=
146 display_cell * tempv = (display_cell*) malloc(sizeof(display_cell));=
147 tempv->next = NULL;=
148 v_pointer->next = tempv;=
149 v_pointer->downdown = (display_cell*) malloc(sizeof(display_cell));=
150 v_pointer=v_pointer->downdown;=
151 }=
152 }=
153 }=
154 if (s_count_prev!=s_count)=
155 {=
156 node_count=0;=
157 }=
158 else if (node_flag==1)=
159 {=
160 display_cell * tempv = (display_cell*) malloc(sizeof(display_cell));=

```

```

node number.....**262**node group.....**0**node area.....**0
node number.....**263**node group.....**1**node area.....**0
node number.....**264**node group.....**0**node area.....**0
node number.....**265**node group.....**0**node area.....**0
node number.....**266**node group.....**1**node area.....**0
node number.....**267**node group.....**0**node area.....**0
node number.....**268**node group.....**0**node area.....**0
node number.....**269**node group.....**1**node area.....**0
node number.....**270**node group.....**0**node area.....**0
node number.....**271**node group.....**0**node area.....**0
node number.....**272**node group.....**1**node area.....**0
node number.....**273**node group.....**1**node area.....**0
node number.....**274**node group.....**1**node area.....**0
node number.....**275**node group.....**0**node area.....**0
node number.....**276**node group.....**0**node area.....**0
node number.....**277**node group.....**1**node area.....**0
node number.....**278**node group.....**0**node area.....**0
node number.....**279**node group.....**0**node area.....**0
node number.....**280**node group.....**0**node area.....**0
node number.....**281**node group.....**1**node area.....**0
node number.....**282**node group.....**1**node area.....**0
node number.....**283**node group.....**1**node area.....**0
area.....9842880
cut set size.....after.....22891
reduction in cutset size is .....10062
cut set size.....before.....32954
Process returned 0 (0x0) execution time : 86.602 s
Press any key to continue.

```

Fig 5. Output terminal results for ibm03

```

C/C++ - FM/Fiduccia_Mattheyses.cpp - Eclipse
File Edit Source Refactor Navigate Search Project Run Window Help

C:\Sukrutha\FM\FM_improved.exe

Fiduccia_Mattheyses.cpp
124 while (getline (myfile2,line) )=
125 {=
126 string first_letter;=
127 s_count_prev=s_count;=
128 if (line.find("s")!=std::string::npos)=
129 {=
130 node_flag=1;=
131 s_count++;=
132 offset=line.find("s");=
133 line_substr=line.substr(1,offset-1);=
134 first_letter = line.substr(0,1);=
135 v_pointer->cname=strtol(line_substr.c_str(),=
136 &first_letter,10);=
137 if (first_letter.compare("a")==0)=
138 {=
139 v_pointer->ap=0;=
140 }=
141 if (first_letter.compare("p")==0)=
142 {=
143 v_pointer->ap=1;=
144 }=
145 h_pointer=v_pointer;=
146 display_cell * tempv = (display_cell*) malloc(sizeof(display_cell));=
147 tempv->next = NULL;=
148 v_pointer->next = tempv;=
149 v_pointer->downdown = (display_cell*) malloc(sizeof(display_cell));=
150 v_pointer=v_pointer->downdown;=
151 }=
152 }=
153 }=
154 if (s_count_prev!=s_count)=
155 {=
156 node_count=0;=
157 }=
158 else if (node_flag==1)=
159 {=
160 display_cell * tempv = (display_cell*) malloc(sizeof(display_cell));=

```

```

node number.....**266**node group.....**1**node area.....**0
node number.....**267**node group.....**1**node area.....**0
node number.....**268**node group.....**0**node area.....**0
node number.....**269**node group.....**0**node area.....**0
node number.....**270**node group.....**1**node area.....**0
node number.....**271**node group.....**1**node area.....**0
node number.....**272**node group.....**0**node area.....**0
node number.....**273**node group.....**1**node area.....**0
node number.....**274**node group.....**1**node area.....**0
node number.....**275**node group.....**0**node area.....**0
node number.....**276**node group.....**1**node area.....**0
node number.....**277**node group.....**1**node area.....**0
node number.....**278**node group.....**1**node area.....**0
node number.....**279**node group.....**1**node area.....**0
node number.....**280**node group.....**1**node area.....**0
node number.....**281**node group.....**0**node area.....**0
node number.....**282**node group.....**1**node area.....**0
node number.....**283**node group.....**1**node area.....**0
node number.....**284**node group.....**0**node area.....**0
node number.....**285**node group.....**1**node area.....**0
node number.....**286**node group.....**1**node area.....**0
node number.....**287**node group.....**0**node area.....**0
area.....9294944
cut set size.....after.....25405
reduction in cutset size is .....11353
cut set size.....before.....36758
Process returned 0 (0x0) execution time : 114.934 s
Press any key to continue.

```

Fig 6. Output terminal results for ibm04



```
124> while (getline (myfile2,line) )=
125> {
126>     string first_letter;
127>     s_count_prev=s_count;
128>     if (line.find("#")!=std::string::npos)=
129>     {
130>         node_flag=1;
131>         s_count++;
132>         offset=line.find("s");
133>         line_substr=line.substr(1,offset-1);
134>         first_letter = line.substr(0,1);
135>         v_pointer->cname=strol(line_substr.c_str());
136>         if (first_letter.compare("a")==0)=
137>         {
138>             v_pointer->ap=0;
139>         }=
140>         if (first_letter.compare("p")==0)=
141>         {
142>             v_pointer->ap=1;
143>         }=
144>
145>         h_pointer=v_pointer;
146>         display_cell * tempv = (display_cell*)malloc
147>         tempv->next = NULL;
148>         v_pointer->next = tempv;
149>         v_pointer->down = (display_cell*)malloc(sizeof
150>         v_pointer=v_pointer->down;
151>     }=
152>
153>
154>     if (s_count_prev!=s_count)=
155>     {
156>         node_count=0;
157>     }=
158>     else if (node_flag==1)=
159>     {
160>         display_cell * tempv = (display_cell*)malloc(sizeof(display_cell));
```

```
node number.....**1180**node group.....**0**node area.....**0
node number.....**1181**node group.....**1**node area.....**0
node number.....**1182**node group.....**1**node area.....**0
node number.....**1183**node group.....**0**node area.....**0
node number.....**1184**node group.....**0**node area.....**0
node number.....**1185**node group.....**0**node area.....**0
node number.....**1186**node group.....**1**node area.....**0
node number.....**1187**node group.....**1**node area.....**0
node number.....**1188**node group.....**0**node area.....**0
node number.....**1189**node group.....**1**node area.....**0
node number.....**1190**node group.....**1**node area.....**0
node number.....**1191**node group.....**1**node area.....**0
node number.....**1192**node group.....**0**node area.....**0
node number.....**1193**node group.....**0**node area.....**0
node number.....**1194**node group.....**0**node area.....**0
node number.....**1195**node group.....**1**node area.....**0
node number.....**1196**node group.....**1**node area.....**0
node number.....**1197**node group.....**0**node area.....**0
node number.....**1198**node group.....**0**node area.....**0
node number.....**1199**node group.....**0**node area.....**0
node number.....**1200**node group.....**1**node area.....**0
node number.....**1201**node group.....**0**node area.....**0
area.....4471520
cut set size.....after.....37233
reduction in cutset size is .....11791
cut set size.....before.....49024
Process returned 0 (0x0)   execution time : 147.096 s
Press any key to continue.
```

Fig 7. Output terminal results for ibm05

```
124> while (getline (myfile2,line) )=
125> {
126>     string first_letter;
127>     s_count_prev=s_count;
128>     if (line.find("#")!=std::string::npos)=
129>     {
130>         node_flag=1;
131>         s_count++;
132>         offset=line.find("s");
133>         line_substr=line.substr(1,offset-1);
134>         first_letter = line.substr(0,1);
135>         v_pointer->cname=strol(line_substr.c_str());
136>         if (first_letter.compare("a")==0)=
137>         {
138>             v_pointer->ap=0;
139>         }=
140>         if (first_letter.compare("p")==0)=
141>         {
142>             v_pointer->ap=1;
143>         }=
144>
145>         h_pointer=v_pointer;
146>         display_cell * tempv = (display_cell*)malloc
147>         tempv->next = NULL;
148>         v_pointer->next = tempv;
149>         v_pointer->down = (display_cell*)mall
150>         v_pointer=v_pointer->down;
151>     }=
152>
153>
154>     if (s_count_prev!=s_count)=
155>     {
156>         node_count=0;
157>     }=
158>     else if (node_flag==1)=
159>     {
160>         display_cell * tempv = (display_cell*)malloc(sizeof(display_cell));
```

```
node number.....**145**node group.....**1**node area.....**0
node number.....**146**node group.....**1**node area.....**0
node number.....**147**node group.....**1**node area.....**0
node number.....**148**node group.....**0**node area.....**0
node number.....**149**node group.....**0**node area.....**0
node number.....**150**node group.....**1**node area.....**0
node number.....**151**node group.....**0**node area.....**0
node number.....**152**node group.....**1**node area.....**0
node number.....**153**node group.....**1**node area.....**0
node number.....**154**node group.....**0**node area.....**0
node number.....**155**node group.....**1**node area.....**0
node number.....**156**node group.....**0**node area.....**0
node number.....**157**node group.....**0**node area.....**0
node number.....**158**node group.....**0**node area.....**0
node number.....**159**node group.....**1**node area.....**0
node number.....**160**node group.....**0**node area.....**0
node number.....**161**node group.....**0**node area.....**0
node number.....**162**node group.....**1**node area.....**0
node number.....**163**node group.....**0**node area.....**0
node number.....**164**node group.....**0**node area.....**0
node number.....**165**node group.....**0**node area.....**0
node number.....**166**node group.....**1**node area.....**0
area.....8577791
cut set size.....after.....33385
reduction in cutset size is .....13424
cut set size.....before.....46809
Process returned 0 (0x0)   execution time : 156.901 s
Press any key to continue.
```

Fig 8. Output terminal results for ibm06

The screenshot shows the Eclipse IDE with a C++ project named 'FM'. The source file 'Fiduccia\_Mattheyses.cpp' is open, showing lines 131 to 167. The code implements a graph partitioning algorithm, including functions for finding 's' and 'p' characters, updating pointers, and allocating memory for 'display\_cell'. The terminal window on the right shows the output of the program, displaying a list of node numbers and their corresponding group and area values. The output ends with 'Process returned 0 (0x0) execution time : 303.000 s' and 'Press any key to continue.'.

```
node number.....**266**node group.....**0**node area.....**0
node number.....**267**node group.....**0**node area.....**0
node number.....**268**node group.....**1**node area.....**0
node number.....**269**node group.....**1**node area.....**0
node number.....**270**node group.....**0**node area.....**0
node number.....**271**node group.....**0**node area.....**0
node number.....**272**node group.....**0**node area.....**0
node number.....**273**node group.....**1**node area.....**0
node number.....**274**node group.....**1**node area.....**0
node number.....**275**node group.....**1**node area.....**0
node number.....**276**node group.....**1**node area.....**0
node number.....**277**node group.....**0**node area.....**0
node number.....**278**node group.....**0**node area.....**0
node number.....**279**node group.....**1**node area.....**0
node number.....**280**node group.....**1**node area.....**0
node number.....**281**node group.....**0**node area.....**0
node number.....**282**node group.....**1**node area.....**0
node number.....**283**node group.....**0**node area.....**0
node number.....**284**node group.....**1**node area.....**0
node number.....**285**node group.....**1**node area.....**0
node number.....**286**node group.....**1**node area.....**0
node number.....**287**node group.....**0**node area.....**0
area.....11829856
cut set size.....after.....44715
reduction in cutset size is .....18796
cut set size.....before.....63511
Process returned 0 (0x0) execution time : 303.000 s
Press any key to continue.
```

Fig 9. Output terminal results for ibm07

The screenshot shows the Eclipse IDE with the same C++ project 'FM'. The source file 'Fiduccia\_Mattheyses.cpp' is open, showing lines 131 to 167. The terminal window on the right shows the output of the program, displaying a list of node numbers and their corresponding group and area values. The output ends with 'Process returned 0 (0x0) execution time : 385.377 s' and 'Press any key to continue.'.

```
node number.....**265**node group.....**1**node area.....**0
node number.....**266**node group.....**1**node area.....**0
node number.....**267**node group.....**0**node area.....**0
node number.....**268**node group.....**0**node area.....**0
node number.....**269**node group.....**0**node area.....**0
node number.....**270**node group.....**1**node area.....**0
node number.....**271**node group.....**1**node area.....**0
node number.....**272**node group.....**0**node area.....**0
node number.....**273**node group.....**1**node area.....**0
node number.....**274**node group.....**1**node area.....**0
node number.....**275**node group.....**1**node area.....**0
node number.....**276**node group.....**0**node area.....**0
node number.....**277**node group.....**0**node area.....**0
node number.....**278**node group.....**0**node area.....**0
node number.....**280**node group.....**1**node area.....**0
node number.....**281**node group.....**1**node area.....**0
node number.....**282**node group.....**0**node area.....**0
node number.....**283**node group.....**0**node area.....**0
node number.....**284**node group.....**0**node area.....**0
node number.....**285**node group.....**1**node area.....**0
node number.....**286**node group.....**1**node area.....**0
area.....13449888
cut set size.....after.....56512
reduction in cutset size is .....28463
cut set size.....before.....76975
Process returned 0 (0x0) execution time : 385.377 s
Press any key to continue.
```

Fig 10. Output terminal results for ibm08

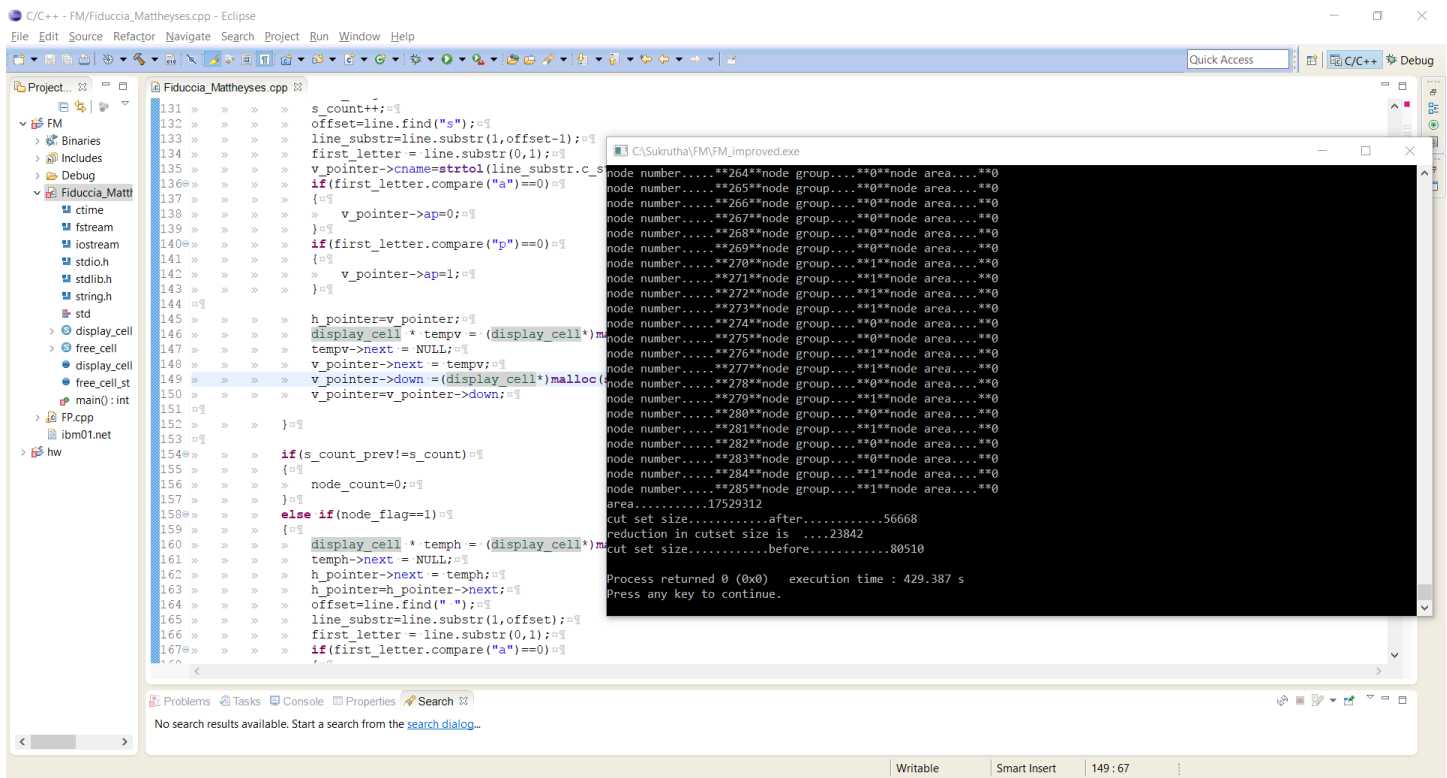


Fig 11. Output terminal results for ibm09

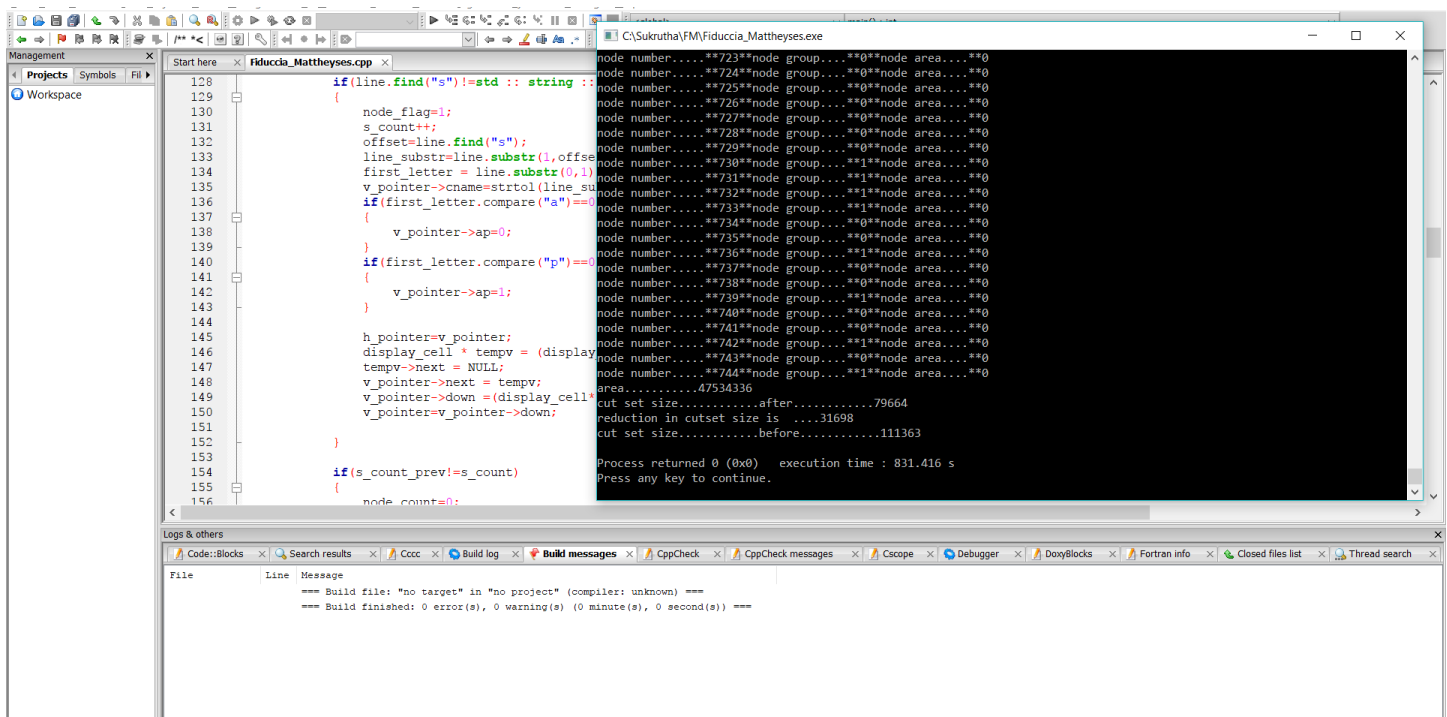


Fig 12. Output terminal results for ibm10

```

102  /*this part is a 2-D linked list*/
103  int node_count=0;
104  int node_flag=0;
105  string line,line_substr;
106  int s_count=0;
107  int s_count_prev=0;
108  display_cell * head = NULL;
109  display_cell * v_pointer = NULL;
110  display_cell * h_pointer = NULL;
111
112  head =(display_cell*)malloc(sizeof(display_cell))
113  v_pointer =(display_cell*)malloc(sizeof(display_cell))
114  h_pointer =(display_cell*)malloc(sizeof(display_cell))
115  display_cell * start = NULL;
116  v_pointer=head;
117  h_pointer=head;
118
119  //bucket formation//////////
120  ifstream myfile2 ("ibm11.net");
121  if (myfile2.is_open())
122  {
123      while (getline (myfile2,line) )
124      {
125          string first_letter;
126          s_count_prev=s_count;
127          if (line.find("s")!=std::string::npos)
128          {
129              node_flag=1;
130
node number.....**385**node group.....**0**node area.....**0
node number.....**386**node group.....**0**node area.....**0
node number.....**387**node group.....**0**node area.....**0
node number.....**388**node group.....**1**node area.....**0
node number.....**389**node group.....**1**node area.....**0
node number.....**390**node group.....**1**node area.....**0
node number.....**391**node group.....**1**node area.....**0
node number.....**392**node group.....**0**node area.....**0
node number.....**393**node group.....**0**node area.....**0
node number.....**394**node group.....**0**node area.....**0
node number.....**395**node group.....**1**node area.....**0
node number.....**396**node group.....**1**node area.....**0
node number.....**397**node group.....**0**node area.....**0
node number.....**398**node group.....**1**node area.....**0
node number.....**399**node group.....**1**node area.....**0
node number.....**400**node group.....**1**node area.....**0
node number.....**401**node group.....**1**node area.....**0
node number.....**402**node group.....**0**node area.....**0
node number.....**403**node group.....**0**node area.....**0
node number.....**404**node group.....**1**node area.....**0
node number.....**405**node group.....**0**node area.....**0
node number.....**406**node group.....**0**node area.....**0
area.....21237408
cut set size.....after.....68921
reduction in cutset size is ....30780
cut set size.....before.....99702
Process returned 0 (0x0)   execution time : 886.394 s
Press any key to continue.

```

Fig 13. Output terminal results for ibm11

```

49  string line1,line2,line3;
50  int offset;
51  ptr_f=head_f;
52  long long int total_area=0;
53  int area_A=0, area_B=0;
54  int counter = 0;
55  ifstream myfile ("ibm12.are");
56
57
58  if (myfile.is_open())
59  {
60      while ( getline (myfile,line1))
61      {
62          counter++;
63          offset=line1.find(" ");
64          line2=line1.substr(1,offset);
65          string first_letter;
66          first_letter = line1.substr(0,1);
67          if (first_letter.compare("a")==0)
68          {
69              ptr_f->ap=0;
70              ptr_f->lock=0;
71          }
72          if (first_letter.compare("p")==0)
73          {
74              ptr_f->ap=1;
75              ptr_f->lock=1;
76          }
77          line3=line1.substr(offset+1,line1.length()
node number.....**616**node group.....**0**node area.....**0
node number.....**617**node group.....**1**node area.....**0
node number.....**618**node group.....**1**node area.....**0
node number.....**619**node group.....**1**node area.....**0
node number.....**620**node group.....**1**node area.....**0
node number.....**621**node group.....**1**node area.....**0
node number.....**622**node group.....**1**node area.....**0
node number.....**623**node group.....**0**node area.....**0
node number.....**624**node group.....**0**node area.....**0
node number.....**625**node group.....**0**node area.....**0
node number.....**626**node group.....**0**node area.....**0
node number.....**627**node group.....**0**node area.....**0
node number.....**628**node group.....**1**node area.....**0
node number.....**629**node group.....**0**node area.....**0
node number.....**630**node group.....**1**node area.....**0
node number.....**631**node group.....**1**node area.....**0
node number.....**632**node group.....**0**node area.....**0
node number.....**633**node group.....**1**node area.....**0
node number.....**634**node group.....**1**node area.....**0
node number.....**635**node group.....**1**node area.....**0
node number.....**636**node group.....**1**node area.....**0
node number.....**637**node group.....**1**node area.....**0
area.....36974848
cut set size.....after.....86935
reduction in cutset size is ....33128
cut set size.....before.....120063
Process returned 0 (0x0)   execution time : 971.316 s
Press any key to continue.

```

Fig 14. Output terminal results for ibm12

```

105 int node_flag=0;
106 string line,line_substr;
107 int s_count=0;
108 int s_count_prev=0;
109 display_cell * head = NULL;
110 display_cell * v_pointer = NULL;
111 display_cell * h_pointer = NULL;
112
113 head =(display_cell*)malloc(sizeof(display_cell));
114 v_pointer =(display_cell*)malloc(sizeof(display_cell));
115 h_pointer =(display_cell*)malloc(sizeof(display_cell));
116 display_cell * start = NULL;
117 v_pointer=head;
118 h_pointer=head;
119
120
121 //bucket formation////////////////////////////////
122 ifstream myfile2 ("ibm13.net");
123 if (myfile2.is_open())
124 {
125     while (getline (myfile2,line) )
126     {
127         string first_letter;
128         s_count_prev=s_count;
129         if (line.find("s")!=std::string::npos)
130         {
131             node_flag=1;
132             s_count++;
133             offset=line.find("s");
134             line_substr=line.substr(1,offset-1);
135         }
136     }
137 }

```

```

C:\Sukrutha\FM\Fiduccia_Mattheyses.exe
node number.....**469**node group.....**0**node area.....**0
node number.....**470**node group.....**0**node area.....**0
node number.....**471**node group.....**0**node area.....**0
node number.....**472**node group.....**0**node area.....**0
node number.....**473**node group.....**1**node area.....**0
node number.....**474**node group.....**1**node area.....**0
node number.....**475**node group.....**1**node area.....**0
node number.....**476**node group.....**1**node area.....**0
node number.....**477**node group.....**0**node area.....**0
node number.....**478**node group.....**0**node area.....**0
node number.....**479**node group.....**0**node area.....**0
node number.....**480**node group.....**0**node area.....**0
node number.....**481**node group.....**0**node area.....**0
node number.....**482**node group.....**0**node area.....**0
node number.....**483**node group.....**1**node area.....**0
node number.....**484**node group.....**1**node area.....**0
node number.....**485**node group.....**1**node area.....**0
node number.....**486**node group.....**0**node area.....**0
node number.....**487**node group.....**1**node area.....**0
node number.....**488**node group.....**0**node area.....**0
node number.....**489**node group.....**0**node area.....**0
node number.....**490**node group.....**0**node area.....**0
area.....25061568
cut set size.....after.....90825
reduction in cutset size is ....37813
cut set size.....before.....128638
Process returned 0 (0x0)   execution time : 1396.868 s
Press any key to continue.

```

Fig 15. Output terminal results for ibm13

```

34 int main()
35 {
36     int pmax;
37     int start_s=clock();
38     /*
39     * ad = 0 if it is cell(a)
40     * ad = 1 if it is pad(p)
41     */
42     /* Distinct elements in the file*/
43     free_cell *head_f = NULL;
44     head_f =(free_cell*)malloc(sizeof(free_cell));
45     free_cell *ptr_f = NULL;
46     ptr_f =(free_cell*)malloc(sizeof(free_cell));
47     string line1,line2,line3;
48     int offset;
49     ptr_f=head_f;
50     long long int total_area=0;
51     int area_A=0, area_B=0;
52     int counter = 0;
53     ifstream myfile ("ibm14.are");
54
55     if (myfile.is_open())
56     {
57         while ( getline (myfile,line1))
58         {
59             counter++;
60         }
61     }
62 }

```

```

C:\Sukrutha\FM\Fiduccia_Mattheyses.exe
node number.....**496**node group.....**1**node area.....**0
node number.....**497**node group.....**1**node area.....**0
node number.....**498**node group.....**1**node area.....**0
node number.....**499**node group.....**0**node area.....**0
node number.....**500**node group.....**1**node area.....**0
node number.....**501**node group.....**1**node area.....**0
node number.....**502**node group.....**1**node area.....**0
node number.....**503**node group.....**0**node area.....**0
node number.....**504**node group.....**0**node area.....**0
node number.....**505**node group.....**1**node area.....**0
node number.....**506**node group.....**0**node area.....**0
node number.....**507**node group.....**1**node area.....**0
node number.....**508**node group.....**1**node area.....**0
node number.....**509**node group.....**1**node area.....**0
node number.....**510**node group.....**0**node area.....**0
node number.....**511**node group.....**0**node area.....**0
node number.....**512**node group.....**0**node area.....**0
node number.....**513**node group.....**1**node area.....**0
node number.....**514**node group.....**0**node area.....**0
node number.....**515**node group.....**1**node area.....**0
node number.....**516**node group.....**1**node area.....**0
node number.....**517**node group.....**1**node area.....**0
area.....28727296
cut set size.....after.....137573
reduction in cutset size is ....59567
cut set size.....before.....197140
Process returned 0 (0x0)   execution time : 3870.845 s
Press any key to continue.

```

Fig 16. Output terminal results for ibm14

**Table for percentage reduction in cutsize:**

<b>IBM File Number</b>	<b>Percentage Reduction in cut set size</b>	<b>Running time</b>
ibm01	32.8%	30.5s
ibm02	28%	67.148s
ibm03	30.53%	86.602s
ibm04	30.88%	114.934s
ibm05	24.5%	147.096s
ibm06	28.7%	156.901s
ibm07	29.6%	303s
ibm08	26.6%	385.377s
ibm09	29.61%	429.387s
ibm10	28.5%	831.416s
ibm11	30.9%	886.394s
ibm12	27.6%	971.316s
ibm13	29.4%	1396.868s
ibm14	30.2%	3870.845s

## **6. Conclusion:**

As the runtime is comparably big for the fast-paced embedded era there can be a few improvements added which will help run the partitioning algorithm faster. The possible improvements are:

- Optimization of the code to reuse the existing code of the bucket structure.
- Run coverage tests at unit level to eliminate redundant modified conditions.
- Extend the two-way partitioning to multiway partitioning and check if the algorithm is consistent
- Feasibility of implementing a different data structure for the bucket instead of the linked list.

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