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Path union of wheel related tail graphs as e-cordial families

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***Abstract:** In this paper we study path union of graphs $P_m(G)$ obtained from attaching a path to wheel W4 graph.*

Key words: **E-cordial, path union, fusion, edge, vertex, wheel. Gear graph.**

Subject Classification: 05C78.

I. INTRODUCTION

The graphs we discuss are simple, connected and finite. For terminology and definitions we depend on Graph Theory by Harary [4], Dynamic survey of graph labeling [3].and West [6].

In 1997 Yilmaz and Cahit [5] introduced a weaker version of edge graceful labeling called E-cordial. The word cordial was used first time in this paper. Let G be a graph with vertex set V and edge set E. Let f be a function that maps E into {0,1} .Define f on V by f(v) = $\sum\{f(uv)/(uv)\in$ E}(mod 2).The function f is called as E cordial labeling if $|e_f(0)-e_f(1)|\le 1$ and $|v_f(0)-v_f(1)|\le 1$. Where $e_f(i)$ is the number of edges labeled with i = 0,1 and v_f (i) is the number of vertices labeled with i = 0,1. We also use $v_f(0,1)$ = (a,b) to denote the number of vertices labeled with 0 are a in number and that with 1 are b in number. Similarly $e_f(0,1)$=(x, y) to denote number of edges labeled with 0 are x in number and that labeled with 1 are y in number. A lot of work has been done in this type of labeling and the above mentioned paper gave rise to number of papers on cordial labeling. A graph that admits E-cordial labeling is called as E- cordial graph. Yilmaz and Cahit has shown that Trees T_n with n vertices and Complete graphs K_n on n vertices are E – cordial iff n is not congruent to 2 (modulo 4). Friendship graph $C_3^{(n)}$ for all n and fans F_n for n not congruent to 1 (mod 4).They observe that a graph with n vertices is not e-cordial if n≡ 2(mod 4). One may refer A Dynamic survey of graph labeling for more details on completed work.

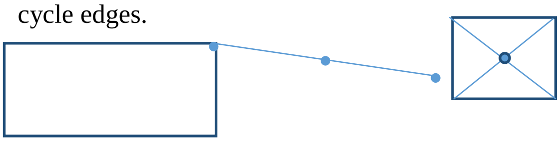
In this paper we discuss path unions of graphs obtained from W_4. WE discuss tailW_4 (P_m).The e-cordial function f is independent of the vertex on G used to fuse on the vertex of path P_m.

II. PRELIMINARIES

Fusion of vertex. [6] Let G be a (p,q) graph. Let u≠v be two vertices of G. We replace them with single vertex w and all edges incident with u and that with v are made incident with w. If a loop is formed is deleted. The new graph has p-1vertices and at least q-1 edges.[6].If uϵG_1 and vϵG_2, where G_1 is (p_1,q_1) and G_2 is (p_2,q_2) graph. Take a new vertex w and all the edges incident to u and v are joined to w and vertices u and v are deleted. The new graph has p_1+p_2-1 vertices and $q_1 + q_2$ edges. Sometimes this is referred as u is identified with v.

Path union of G i.e.P_m (G) [1] is obtained by taking a path P_m and m copies of graph G. Fuse a copy each of G at every vertex of path at given fixed point on G. It has mp vertices and mq +m-1 edges, where G is a (p,q) graph. If we change the vertex on G that is fused with vertex of Pm then we generally get a path union non isomorphic to earlier structure. In this paper we define a e-cordial function f that does not depends on which vertex of given graph G is fused to obtain path union. This allows us to obtain path union in which the same graph G is fused with vertices of P_m at different vertices of G, as our choice and the same function f is applicable to all such structures that are possible on P_m(G). 3) Tail graph tail (G,Pm) is obtained from G by fusing an end point of Pm with a vertex og G. If G is a (p,q) graph then tail(G,Pm) has p+m-1 vertices and q+m-1 edges. Below is copy of tailC_4,p_3)

Wheel graph Wn. Take a cycle Cn and a vertex w not on Cn. Join every vertex of Cn by an edge each to w.The resultant graph is wheel Wn. Sometimes the same graph is shown by W_{n+1}.It has n+1 vertices and 2n edges. The edges incident with w are called as pokes and vertex as hub. The other edges that lie on cycle Cn are called as cycle edges.



In all the diagrams given below the number indicates edge label numbers.

III. RESULTS

Theorem 1. P_m(G) is e-cordial where G= tail (W_4,P_4) is obtained by fusing P_4 at it's pendent vertex with any of W_4 vertex.

Proof. We take a path P_m=(v_1, v_2, …v_m) and at each of it's vertex fuse a copy of G at a fixed vertex of G. Define a function f:E(G)→ {0,1} as follows: Label of every edge on path P_m is '0'. Atail can be fused with W_4 at any C_4 vertex of W_4or at hub. Using f we get following labeled copies of tail(W_4,P_4) which is E- cordial. We fuse Type A label with every vertex of P_m resulting in structure 1 and Type B in resulting structure 2.In any case it gives us E-cordial labeled copy of G.Moreover it is important to note that we get a mixed path union if we use type A label and Type B label alternately on P_m..Also we can fuse G at any of it's vertex with P_m and get some different

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(non isomorphic to other structures) structure.The same function f will work for all structures as e-cordial labeling

Type A
Structure 1

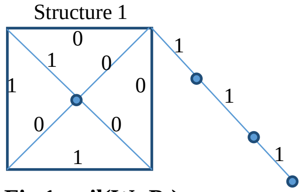

Fig 1: tail(W_4,P_4)
: $v_f(0,1)$ = (4,4),
$e_f(0,1)$ = (5,6)

Type B
Structure 2

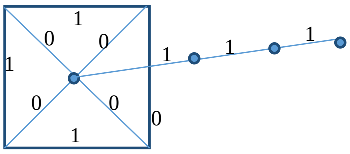

Fig 2: tail(W_4,P_4)
: $v_f(0,1)$ = (4,4),
$e_f(0,1)$ = (5,6)

Fuse the above labeled copy with each vertex at given fixed point. The resultant graph has label distribution given by $v_f(0,1) = (4m,4m)$), $e_f(0,1) = (5+6(m-1),6+6(m-1))$ where m = 1, 2, 3.Thus the graph is e-cordial for all m. .#

Theorem 2 $P_m(G)$ is e-cordial iff m is not congruent to 2 (mod 4) where G = tail(w_4,P_3) is obtained by fusing P_3 at it's pendent vertex with any of W_4 vertex.

Type A1
Structure 1

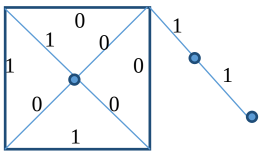

Fig .3: tail(W_4,P_3)
: $v_f(0,1)$ = (3,4),
$e_f(0,1)$ = (5,5)

Type B1
Structure 2

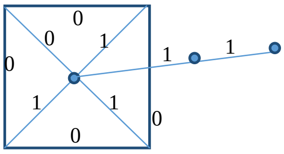

Fig 4: tail(W_4,P_3)
: $v_f(0,1)$ = (3,4),
$e_f(0,1)$ = (5,5)

Type A2
Structure 1

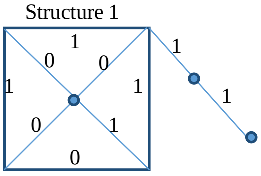

Fig 5: tail(W_4,P_3)
: $v_f(0,1)$ = (3,4),
$e_f(0,1)$ = (4,6)

Type B2
Structure 2

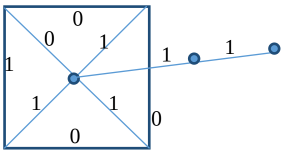

Fig .6: tail(W_4,P_3)
: $v_f(0,1)$ = (3,4),
$e_f(0,1)$ = (4,6)

Type A3
Structure 1

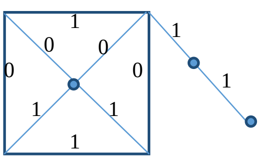

Fig 7 tail(W_4,P_3) :
$v_f(0,1)$ = (5,2),
$e_f(0,1)$ = (4,6)

Type B3
Structure 2

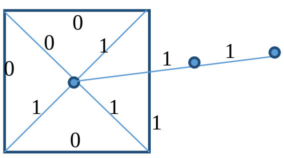

Fig .8 :
tail(W_4,P_3) :
$v_f(0,1)$ = (5,2),

Proof. We take a path $P_m=(v_1, v_2, \ldots v_m)$ and at each of it's vertex fuse a copy of G at a fixed vertex of G. Define a function f:E(G)→ {0,1} as follows: Label of every edge on path P_m is '0'. A tail can be fused with W_4 at any C_4 vertex of W_4 resulting in structure 1 or if tail is fused at hub resulting in structure 2. Using f we get labeled copies of tail(W_4 ,P_3) as Type A1, type A2 and Type A3 in structure 1 and Type B1, type B2 and Type B3 in structure 2.Of these only Type A1 and Type B1 are E-cordial.

To obtain structure 1,we fuse Type A1 at vertex vi of P_m when i =1 and i≡3,0 (mod 4) and Type A3 when i =2 and (i>1)i≡2 (mod 4) , Type A2 label when(i>1) i≡1(mod 4) with vertex vi of P_m resulting in structure 1 .Similarly to obtain structure 2 We fuse Type B1 when i =1 and i≡3,0 (mod 4) and Type B3 when i =2 and (i>1) i≡2 (mod 4) , Type B2 label when(i>1) i≡1(mod 4) with vertex v_i of P_m resulting in structure 2. In both cases it gives us E-cordial labeled copy of G.Moreover it is important to note that we get a mixed path union if we use type Ai label in place of Type Bi label alternately on vertices vi of P_m resulting in e-cordial labeling. This is valid in both structures, instructure 1 and in structure 2. The same function f will work for all structures and produce e-cordial labeling.

The resultant graph has label distribution given by (for both structures)

$v_f(0,1) = (3+14x,4+14x)$), $e_f(0,1) = (5+22x,5+22x)$ where m = 2x+1 and x= 0,1, 2, 3..

$v_f(0,1) = (8+14x,6+14x)$), $e_f(0,1) = (10+22x,11+22x)$ where m = 2x+2 and x=0, 1, 2, 3..

$v_f(0,1) = (11+14x,10+14x)$), $e_f(0,1) = (16+22x,16+22x)$ where m = 2x+3 and x= 0,1, 2, 3..

$v_f(0,1) = (14x,14x)$), $e_f(0,1) = (22x,22x-1)$ where m = 4x and x= 1, 2, 3.Thus the graph is e-cordial for all m not congruent to 2 (mod 4).#

Theorem.3 $P_m(G)$ is e-cordial iff m is not congruent to 2 (mod 4) where G= tail(W_4,P_5) is obtained by fusing P_5 at it's pendent vertex with any of W_4 vertex.

Proof: We take a path $P_m=(v_1, v_2, \ldots v_m)$ and at each of it's vertex fuse a copy of G at a fixed vertex of G. Define a function f:E(G)→ {0,1} as follows: Label of every edge on path P_m is '0'. A tail can be fused with W_4 at any C_4 vertex of W_4 resulting in structure 1 or if tail is fused at hub resulting in structure 2.

Type A1
Structure 1

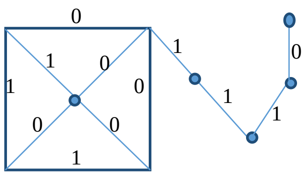

Fig.9: tail(W_4,P_5)
: $v_f(0,1)$ = (5,4),
$e_f(0,1)$ = (6,6)

Type B1
Structure 2

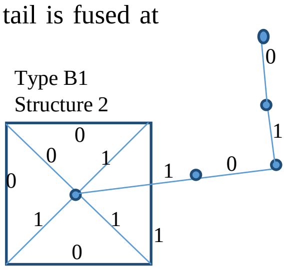

Fig .10 :
tail(W_4,P_5) :
$v_f(0,1)$ = (5,4),

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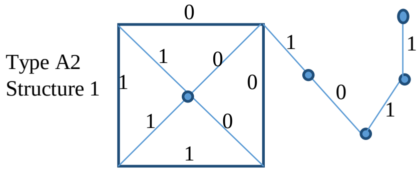

Fig 11: tail(W_4,P_5) : $v_f(0,1)$ = (3,6),

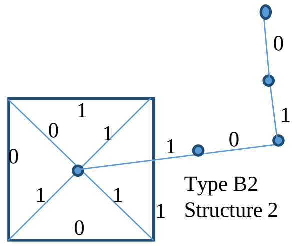

Fig .12 : tail(W_4,P_5) : $v_f(0,1)$ = (3,6),

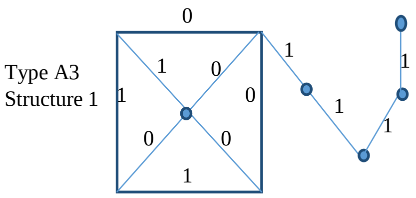

Fig 13: tail(W_4,P_5) : $v_f(0,1)$ = (5,4), $e_f(0,1)$ = (5,7)

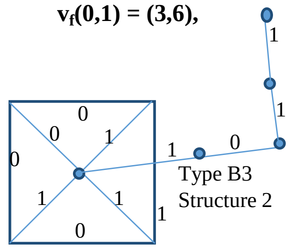

Fig .14 : tail(W_4,P_5) : $v_f(0,1)$ = (5,4), $e_f(0,1)$ = (5,7)

To obtain structure 1, we fuse Type A1 at vertex v_i of P_m when i =1 and i≡ 3,0 (mod 4) and Type A2 when i =2 and i≡2 (mod 4) , Type A3 label when (i>1)i≡ 1(mod 4) with vertex vi of P_m resulting in structure 1 .Similarly to obtain structure 2 we fuse Type B1 at vertex v_i of P_m when i =1 and i≡ 3,0 (mod 4) and Type B2 when i =2 and i≡2 (mod 4) , Type B3 label when (i>1) i≡ 1(mod 4) with vertex vi of P_m

In both cases it gives us E-cordial labeled copy of G.Moreover it is important to note that we get a mixed path union if we use type Ai label in place of Type Bi label alternately on vertices vi of P_m resulting in e-cordial labeling. This is valid in both structures, instructure 1 and in structure 2. The same function f will work for all structures and produce e-cordial labeling.The resultant graph has label distribution given by (for both structures).

$v_f(0,1)$ = (5+18x,4+18x)), $e_f(0,1)$ = (6+26x,6+26x) where m = 2x+1 and x= 0,1, 2, 3..

$v_f(0,1)$ = (8+18x,10+18x)), $e_f(0,1)$ = (12+26x,13+26x) where m = 2x+2 and x=0, 1, 2, 3..

$v_f(0,1)$ = (13+18x,14+18x)), $e_f(0,1)$ = (19+26x,19+26x) where m = 2x+3 and x= 0,1, 2, 3..

$v_f(0,1)$ = (18x,18x)), $e_f(0,1)$ = (26x,26x-1) where m = 4x and x= 1, 2, 3..

Thus the graph is e-cordial for all m not congruent to 2 (mod 4).#

Theorem.4 P_m(G) is e-cordial iff m is not congruent to 2 (mod 4) where G is tail(W_4,$2P_2$)

Proof: We take a path P_m=(v_1, v_2, …v_m) and at each of it's vertex fuse a copy of G at a fixed vertex of G. Define a function f:E(G)→ {0,1} as follows: Label of every edge on path P_m is '0'. Two tails can be fused with W_4 at any C_4 vertex of W_4 resulting in structure 1 or at hub resulting in structure 2. Using f we get labeled copies of tail(W_4 ,$2P_2$) as Type A1, type A2 and Type A3 in structure 1 and Type B1, type B2 and Type B3 in structure 2.Of these only Type A1 and Type B1 are E- cordial.In both cases it gives us E-cordial labeled copy of G.

Moreover it is important to note that we get a mixed path union if we use type Ai label in place of Type Bi label alternately on vertices vi of P_m resulting in e-cordial labeling.This is valid in both structures, instructure 1 and in structure 2. Also if we obtain a path union of G in which G is fused with vertex of Pm at random vertex of G ,the same function f will work for all structures and produce e-cordial labeling.The resultant graph has label distribution given by (for both structures)

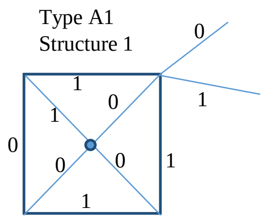

Fig 15: tail(W_4,$2P_2$) : $v_f(0,1)$ = (3,4), $e_f(0,1)$ = (5,5)

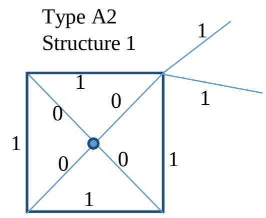

Fig 16: tail(W_4,$2P_2$) : $v_f(0,1)$ = (5,2), $e_f(0,1)$ = (4,6)

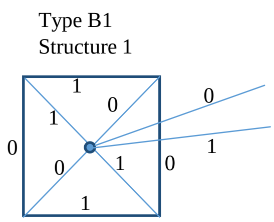

Fig.17: tail(W_4,$2P_2$) : $v_f(0,1)$ = (3,4), $e_f(0,1)$ = (5,5)

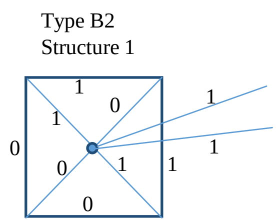

Fig 18: tail(W_4,$2P_2$) : $v_f(0,1)$ = (5,2), $e_f(0,1)$ = (4,6)

To obtain structure 1, we fuse Type A1 at vertex v_i of P_m when i =1 and i≡ 3,0 (mod 4) and Type A2 when i =2 and i≡2 (mod 4) , Type A3 label when (i>1) i≡ 1(mod 4) with vertex vi of P_m resulting in structure 1 .Similarly to obtain structure 2 we fuse Type B1 at vertex v_i of P_m when i =1 and i≡ 3,0 (mod 4) and Type B2 when i =2 and i≡2 (mod 4) , Type B3 label when (i>1) i≡ 1(mod 4) with vertex vi of P_m

$v_f(0,1)$ = (3+14x,4+14x)), $e_f(0,1)$ = (5+22x,5+22x) where m = 2x+1 and x= 0,1, 2, 3..

$v_f(0,1)$ = (8+14x,6+14x)), $e_f(0,1)$ = (10+22x,11+22x) where m = 2x+2 and x=0, 1, 2, 3..

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$v_f(0,1) = (11+18x,10+18x))$, $e_f(0,1) = (16+22x,16+22x)$ where m = 2x+3 and x= 0,1, 2, 3..

$v_f(0,1) = (14x,14x))$, $e_f(0,1) = (22x,22x-1)$ where m = 4x and x= 1, 2, 3..

Thus the graph is e-cordial for all m not congruent to 2 (mod 4).#

Theorem4.5 $P_m(G)$ is e-cordial iff m not congruent to 2 (mod 4) where G= tail(W_4,2P_4) is obtained by fusing two copies of P_4 at it's pendent vertex with any of W_4 vertex Proof:We take a path $P_m=(v_1, v_2, \ldots v_m)$ and at each of it's vertex fuse a copy of G at a fixed vertex of G. Define a function f:E(G)→ {0,1} as follows: Label of every edge on path P_m is '0'. Two tails can be fused with W_4 at any C_4 vertex of W_4 resulting in structure 1 or at hub resulting in structure 2. Using f we get labeled copies of tail(W_4 ,2P_2) as Type A1, type A2 and Type A3 in structure 1 and Type B1, type B2 and Type B3 in structure 2.Of these only Type A1 and Type B1 are E- cordial.In both cases it gives us E-cordial labeled copy of G.

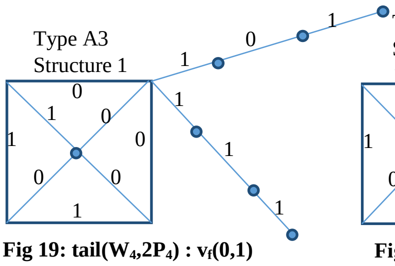

Fig 19: tail(W_4,2P_4) : $v_f(0,1)$ = (5,6), $e_f(0,1)$ = (6,8)

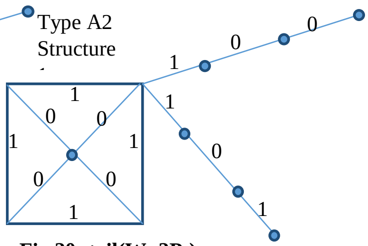

Fig 20: tail(W_4,2P_4) : $v_f(0,1)$ = (7,4), $e_f(0,1)$ = (7,7)

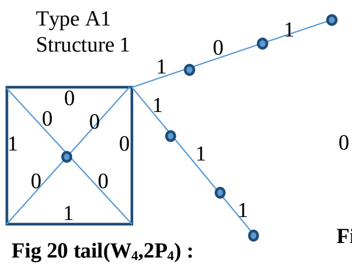

Fig 20 tail(W_4,2P_4) : $v_f(0,1)$ = (5,6), $e_f(0,1)$ = (7,7)

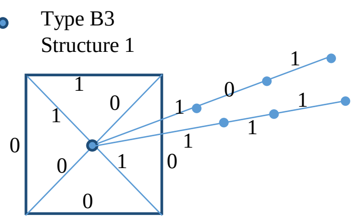

Fig 21: tail(W_4,2P_4) : $v_f(0,1)$ = (5,6), $e_f(0,1)$ = (6,8)

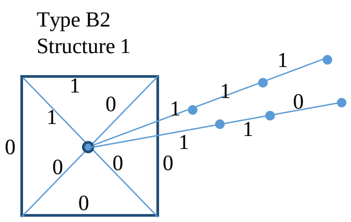

Fig 22: tail(W_4,2P_4) : $v_f(0,1)$ = (7,4), $e_f(0,1)$ = (7,7)

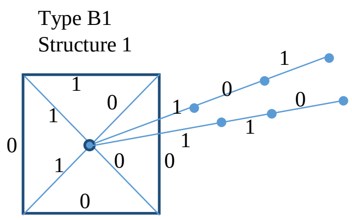

Fig 23: tail(W_4,2P_4) : $v_f(0,1)$ = (5,6), $e_f(0,1)$ = (7,7)

To obtain structure 1, we fuse Type A1 at vertex vi of P_m when i≡1,0 (mod 4) and Type A2 when i≡2 (mod 4) , Type A3 label when i≡3(mod 4) with vertex vi of P_m resulting in structure 1 .Similarly to obtain structure 2 we fuse Type B1 at vertex vi of P_m when i≡ 1,0 (mod 4) and Type B2 when i≡2 (mod 4) , Type B3 label when i≡3(mod 4) with vertex vi of P_m.

Moreover it is important to note that we get a mixed path union if we use type Ai label in place of Type Bi label alternately on vertices vi of P_m resulting in e-cordial labeling (i= 1, 2, 3).This is valid in both structures, instructure 1 and in structure 2. The same function f will work for all structures and produce e-cordial labeling.The same function f allows us to design a path union in which at each v_i(i= 1, 2, ..m) on P_m , G may be fused at different vertex on G with v_i of P_m then also function f works as e-cordial function. The resultant graph has label distribution given by (for both structures) For both structures the label number distribution is given by :

$v_f(0,1) = (5+22x,6+22x))$, $e_f(0,1) = (7+30x,7+30x)$ where m = 2x+1 and x= 0,1, 2, 3..

$v_f(0,1) = (12+22x,10+22x))$, $e_f(0,1) = (15+30x,14+30x)$ where m = 2x+2 and x=0, 1, 2, 3..

$v_f(0,1) = (17+22x,16+22x))$, $e_f(0,1) = (22+22x,22+30x)$ where m = 2x+3 and x= 0,1, 2, 3..

$v_f(0,1) = (22x,22x))$, $e_f(0,1) = (30x,30x-1)$ where m = 4x and x= 1, 2, 3..

Thus the graph is e-cordial for all m not congruent to 2 (mod 4).#

Theorem4.6 $P_m(G)$ is e-cordial iff m not congruent to 2 (mod 4) where G= tail(W_4,2P_3) is obtained by fusing two copies of P_4 at it's pendent vertex with any of W_4 vertex

Proof:We take a path $P_m=(v_1, v_2, \ldots v_m)$ and at each of it's vertex fuse a copy of G at a fixed vertex of G. Define a function f:E(G)→ {0,1} as follows: Label of every edge on path P_m is '0'. Two tails can be fused with W_4 at any C_4 vertex of W_4 resulting in structure 1 or at hub resulting in structure 2. Using f we get labeled copies of tail(W_4 ,2P_2) as Type A1, type A2 and Type A3 in structure 1 and Type B1, type B2 and Type B3 in structure 2.Of these only Type A1 and Type B1 are E- cordial.In both cases it gives us E-cordial labeled copy of G.

To obtain structure 1, we fuse Type A1 at vertex vi of P_m when i =1 and i≡ 3,0 (mod 4) and Type A2 when i≡2 (mod 4) , Type A3 label when (i>1)i≡1(mod 4) with vertex vi of P_m resulting in structure 1 .Similarly to obtain structure 2 we fuse Type B1 at vertex vi of P_m when i =1 and i≡ 3,0 (mod 4) and Type B2 when i =2

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and i≡2 (mod 4) , Type B3 label when (i>1) i≡ 1(mod 4) with vertex vi of P_m.

Moreover it is important to note that we get a mixed path union if we use type Ai label in place of Type Bi label alternately on vertices vi of P_m resulting in e-cordial labeling (i= 1, 2, 3).This is valid in both structures, instructure 1 and in structure 2. The same function f will work for all structures and produce e-cordial labeling.The same function f allows us to design a path union in which at each v_i(i= 1, 2, ..m) on P_m , G may be fused at different vertex on G. The resultant graph has label distribution given by (for both structures).

For both structures the label number distribution is given by :

$v_f(0,1) = (5+18x,4+18x))$, $e_f(0,1) = (6+26x,6+26x)$ where m = 2x+1 and x= 0,1, 2, 3..

$v_f(0,1) = (8+18x,10+18x))$, $e_f(0,1) = (12+26x,13+26x)$ where m = 2x+2 and x=0, 1, 2, 3..

$v_f(0,1) = (13+18x,14+18x))$, $e_f(0,1) = (19+26x,19+26x)$ where m = 2x+3 and x= 0,1, 2, 3..

$v_f(0,1) = (18x,18x))$, $e_f(0,1) = (26x,26x-1)$ where m = 4x and x= 1, 2, 3..

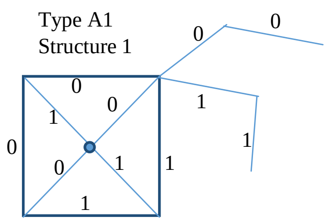

Fig 24: tail(W_4,2P_3) : $v_f(0,1) = (5,4)$, $e_f(0,1) = (6,6)$

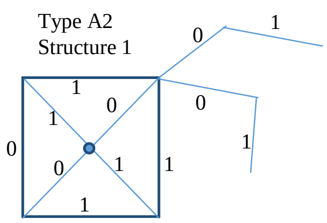

Fig 25: tail(W_4,2P_3) : $v_f(0,1) = (3,6)$, $e_f(0,1) = (5,7)$

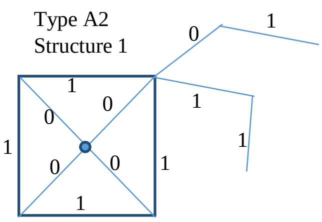

Fig 26: tail(W_4,2P_3) : $v_f(0,1) = (5,4)$, $e_f(0,1) = (5,7)$

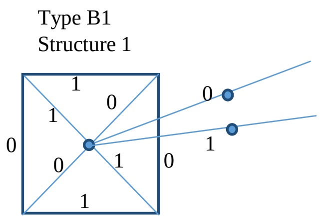

Fig 27: tail(W_4,2P_2) : $v_f(0,1) = (5,4)$, $e_f(0,1) = (6,6)$

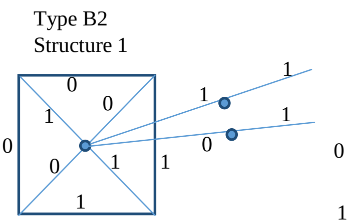

Fig 28: tail(W_4,2P_2) : $v_f(0,1) = (3,6)$, $e_f(0,1) = (5,7)$

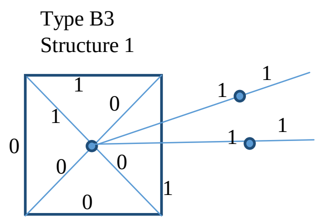

Fig 29: tail(W_4, 2P_2) : $v_f(0,1) = (5,4)$, $e_f(0,1) = (5,7)$

Thus the graph is e-cordial for all m not congruent to 2 (mod 4).#

IV. CONCLUSION

In this paper we construct path union different families of graphs from W4 andpaths attached to it.We have arrived at following results.

1)1 P_m(G) is e-cordial where G= tail(W_4,P_4) is obtained by fusing P_4 at it's pendent vertex with any of W_4 vertex

2)P_m(G) is e-cordial iff m is not congruent to 2 (mod 4) where G = tail(w_4,P_3) is obtained by fusing P_3 at it's pendent vertex with any of W_4 vertex

3)P_m(G) is e-cordial iff m is not congruent to 2 (mod 4) where G= tail(W_4,P_5) is obtained by fusing P_5 at it's pendent vertex with any of W_4 vertex.

4)P_m(G) is e-cordial iff m is not congruent to 2 (mod 4) where G is tail(W_4,2P_2)

5)P_m(G) is e-cordial iffm not congruent to 2 (mod 4) where G= tail(W_4,2P_4) is obtained by fusing two copies of P_4 at it's pendent vertex with any of W_4 vertex

6)P_m(G) is e-cordial iffm not congruent to 2 (mod 4) where G= tail(W_4,2P_3) is obtained by fusing two copies of P_4 at it's pendent vertex with any of W_4 vertex.

We also observe certain pattern repeated in construction of these graphs and another thing that a graph on n vertices is not e-cordial if n ≡ 2 (mod 4).

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