Palestine Journal of Mathematics

Vol. 10(1)(2021) , 53–62

On r-dynamic Coloring of Double Star Graph Families

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Communicated by Ayman Badawi

MSC 2010 Classifications: 05C15.

Keywords and phrases: r-dynamic coloring, Double star graph, Middle graph, Total graph, Central graph and Line graph.

Abstract. An r-dynamic proper k-coloring of a graph G is a proper k-coloring of G such that every vertex in $V(G)$ has neighbors in atleast min $\{r, d(v)\}$ different color classes. The r-dynamic chromatic number of a graph G is the minimum k such that G has an r-dynamic coloring with k colors. In this paper we investigate the r-dynamic chromatic number for the Central graph, Middle graph, Total graph and Line graph of Double star graph.

1 Introduction

In this paper, all graphs are assumed to be simple and finite. The r-dynamic chromatic number, introduced by Montgomery [10] and written as $\chi_r(G)$, is the minimum k such that G has an r-dynamic proper k-coloring. An r-dynamic coloring of a graph G is a map c from $V(G)$ to the set of colors such that (i)if $uv \in E(G)$, then $c(u) \neq c(v)$, and (ii) for each vertex $v \in V(G), |c(N(v))| \geq min\{r, d(v)\}$, where $N(v)$ denotes the set of vertices adjacent to v and $d(v)$ its degree.The first condition characterizes proper colorings, the adjacency condition and second condition is double-adjacency condition [13]. The 1-dynamic chromatic number of a graph G is equal to its chromatic number. The 2-dynamic chromatic number of a graph has been studied under the name dynamic chromatic number in [1, 2, 3, 4, 7].

There are many upper bounds and lower bounds for $\chi_d(G)$ in terms of graph parameters. For example, For a graph G with $\Delta(G) \geq 3$, Lai et al. [7] proved that $\chi_d(G) \leq \Delta(G) + 1$. An upper bound for the dynamic chromatic number of a d-regular graph G in terms of $\chi(G)$ and the independence number of G, $\alpha(G)$, was introduced in [5]. In fact, it was proved that $\chi_d(G) \leq \chi(G) + 2log_2\alpha(G) + 3$.

Li et al. proved in [9] that the computational complexity of $\chi_d(G)$ for a 3-regular graphs is an NP-complete problem. Furthermore, Li and Zhou [8] showed that whether there exists a 3-dynamic coloring, for a claw free graph with the maximum degree 3, is NP-complete.

In this paper, we study the r-dynamic chromatic number for middle, total, central and line graph of Double star graph. Most known papers concern r-dynamic coloring only for small values of r. In this paper, we consider r-dynamic coloring for all r between δ and Δ [14].

2 Preliminaries

The middle graph [11] of G, is defined with the vertex set $V(G) \cup E(G)$ where two vertices are adjacent iff they are either adjacent edges of G or one is the vertex and other is an edge incident with it and it is denoted by $M(G)$.

The total graph [11] of G, has vertex set $V(G) \cup E(G)$, and edges joining all elements of this vertex set which are adjacent or incident in G

The central graph [12] $C(G)$ of a graph G is obtained from G by adding an extra vertex on each edge of G, and then joining each pair of vertices of the original graph which were previously non-adjacent.

The line graph [6] of G denoted by $L(G)$ is the graph whose vertex set is the edge set of G. Two vertices of $L(G)$ are adjacent whenever the corresponding edges of G are adjacent.

Theorem 2.1. *For any Double star graph $K_{1,n,n}$, the r-dynamic chromatic number*

$$\chi_r(C(K_{1,n,n})) = \begin{cases} n+1, r=1 \\ 2n+1, 2 \le r \le \Delta - 1 \\ 3n+1, r \ge \Delta \end{cases}$$

Proof. First we apply the definition of Central graph on $K_{1,n,n}$.

Let the edge vv_i, v_iw_i be subdivided by the vertices $e_i(1 \le i \le n)$, $e_i'(1 \le i \le n)$ in $K_{1,n,n}$.

Clearly $V(C(K_{1,n,n}))$ = $\{v\} \cup \{v_i : 1 \le i \le n\} \cup \{w_i : 1 \le i \le n\} \cup \{e_i : 1 \le i \le n\}$ $\cup \{e_i' : 1 \le i \le n\}$. The vertices $v_i(1 \le i \le n)$ induce a clique of order n (say K_n) and the vertices $v, u_i(1 \le i \le n)$ induce a clique of order $n+1$ (say K_{n+1}) in $C(K_{1,n,n})$ respectively. Thus we have $\chi_r(C(K_{1,n,n})) \ge n+1$.

Case 1: For $r = 1$

Consider the color class $C_1 = \{c_1, c_2, c_3, .., c_{(n+1)}\}$
Assign the r-dynamic coloring to $C(K_{1,n,n})$ by algorithm 2.1.1
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(C(K_{1,n,n})) = n+1$.

Case 2: For $r = 2 \le r \le \Delta - 1$

Consider the color class $C_2 = \{c_1, c_2, c_3, .., c_{(2n+1)}\}$
Assign the r-dynamic coloring to $C(K_{1,n,n})$ by algorithm 2.1.2
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(C(K_{1,n,n})) = 2n+1$.

Case 3: For $r \ge \Delta$

Consider the color class $C_3 = \{c_1, c_2, c_3, .., c_{(3n+1)}\}$
Assign the r-dynamic coloring to $C(K_{1,n,n})$ by algorithm 2.1.3
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(C(K_{1,n,n})) = 3n+1$. □

Algorithm 2.1.1

Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $C(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;
$C(e_i) = i$;
}
$V_2 = \{v\}$;
$C(v) = n+1$;
for $i = 1$ to $n-1$
{
$V_3 = \{v_i\}$;
$C(v_i) = i+1$;
}
$C(v_n) = 1$;
for $i = 1$ to n
{
$V_4 = \{e_i'\}$;
$C(e_i') = n+1$;
}
for $i = 1$ to $n-1$
{
$V_5 = \{w_i\}$;
$C(w_i) = i+1$;
}
$C(w_n) = 1$;

$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5$;
end
Algorithm 2.1.2
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $C(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;
$C(e_i) = i$;
}
$V_2 = \{v\}$;
$C(v) = n + 1$;
for $i = 1$ to $n - 1$
{
$V_3 = \{v_i\}$;
$C(v_i) = i + 1$;
}
$C(v_n) = 1$;
for $i = 1$ to n
{
$V_4 = \{e'_i\}$;
$C(e'_i) = n + 1$;
}
for $i = 1$ to n
{
$V_5 = \{w_i\}$;
$C(w_i) = n + i + 1$;
}
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5$;
end
Algorithm 2.1.3
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $C(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;
$C(e_i) = i$;
}
$V_2 = \{v\}$;
$C(v) = n + 1$;
for $i = 1$ to $n - 1$
{
$V_3 = \{v_i\}$;
$C(v_i) = i + 1$;
}
$C(v_n) = 1$;
for $i = 1$ to n
{
$V_4 = \{e'_i\}$;
$C(e'_i) = 2n + i + 1$;
}
for $i = 1$ to n
{
$V_5 = \{w_i\}$;
$C(w_i) = n + i + 1$;

}
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5$;
end

Theorem 2.2. *For any Double star graph $K_{1,n,n}$, the r-dynamic chromatic number*

$$\chi_r(M(K_{1,n,n})) = \begin{cases} n+1, 1 \leq r \leq n \\ n+2, r = n+1 \\ n+3, r \geq \Delta \end{cases}$$

Proof. By definition of middle graph, each edge vv_i, v_iw_i be subdivided by the vertices $e_i(1 \leq i \leq n)$, $e'_i(1 \leq i \leq n)$ in $K_{1,n,n}$ and the vertices v, e_i induce a clique of order $n+1$(say K_{n+1}) in $M(K_{1,n,n})$.
i.e.,$V(M(K_{1,n,n}))$ = $\{v\} \cup \{v_i : 1 \leq i \leq n\} \cup \{w_i : 1 \leq i \leq n\} \cup \{e_i : 1 \leq i \leq n\} \cup \{e'_i : 1 \leq i \leq n\}$.

Thus we have, $\chi_r(M(K_{1,n,n})) \geq n+1$.

Case 1: For $1 \leq r \leq n$
Consider the color class $C_1 = \{c_1, c_2, c_3, .., c_{(n+1)}\}$
Assign the r-dynamic coloring to $M(K_{1,n,n})$ by algorithm 2.2.1
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Thus we have , $\chi_r(M(K_{1,n,n})) = n+1$ if $1 \leq r \leq n$.

Case 2: For $r = n+1$
Consider the color class $C_2 = \{c_1, c_2, c_3, .., c_{(n+1)}, c_{(n+2)}\}$
Assign the r-dynamic coloring to $M(K_{1,n,n})$ by algorithm 2.2.2
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled. Hence , $\chi_r(M(K_{1,n,n})) = n+2$ if $r = n+1$.

Case 3: For $r = \Delta$
Consider the color class $C_3 = \{c_1, c_2, c_3, .., c_n, c_{(n+1)}, c_{(n+2)}, c_{(n+3)}\}$
Assign the r-dynamic coloring to $M(K_{1,n,n})$ by algorithm 2.2.3
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled. Hence $\chi_r(M(K_{1,n,n})) = n+3$ if $r \geq \Delta$.

□

Algorithm 2.2.1
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $M(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;
$C(e_i) = i$;
}
$V_2 = \{v\}$;
$C(v) = n+1$;
for $i = 1$ to n
{
$V_3 = \{v_i\}$;
$C(v_i) = n+1$;
}
for $i = 1$ to $n-1$
{
$V_4 = \{e'_i\}$;
$C(e'_i) = i+1$;
}

$C(e'_n) = 1;$
for $i = 1$ to $n - 2$
{
$V_5 = \{w_i\};$
$C(w_i) = i + 2;$
}
$C(w_{n-1}) = 1;$
$C(w_n) = 2;$
}
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5;$
end
Algorithm 2.2.2
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $M(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\};$
$C(e_i) = i;$
}
$V_2 = \{v\};$
$C(v) = n + 1;$
for $i = 1$ to n
{
$V_3 = \{v_i\};$
$C(v_i) = n + 2;$
}
for $i = 1$ to n
{
$V_4 = \{e'_i\};$
$C(e'_i) = n + 1;$
}
for $i = 1$ to $n - 1$
{
$V_5 = \{w_i\};$
$C(w_i) = i + 1;$
}
$C(w_n) = 1;$
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5;$
end
Algorithm 2.2.3
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $M(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\};$
$C(e_i) = i;$
}
$V_2 = \{v\};$
$C(v) = n + 1;$
for $i = 1$ to n
{
$V_3 = \{v_i\};$
$C(v_i) = n + 2;$
}
for $i = 1$ to n

{
$V_4 = \{e'_i\}$;
$C(e'_i) = n + 3$;
}
for $i = 1$ to n
{
$V_5 = \{w_i\}$;
$C(w_i) = n + 1$;
}
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5$;
end

Theorem 2.3. *For any Double star graph $K_{1,n,n}$, the r-dynamic chromatic number,*

$$\chi_r(T(K_{1,n,n})) = \begin{cases} n+1, 1 \le r \le n \\ r+1, n+1 \le r \le \Delta - 2 \\ 2n, r = \Delta - 1 \\ 2n+1, r \ge \Delta \end{cases}$$

Proof. By definition of Total graph, each edge vv_i, v_iw_i be subdivided by the vertices $e_i(1 \le i \le n)$, $e'_i(1 \le i \le n)$ in $K_{1,n,n}$ and the vertices v, e_i induce a clique of order $n+1$(say K_{n+1}) in $T(K_{1,n,n})$.
i.e.,$V(T(K_{1,n,n}))$ = $\{v\} \cup \{v_i : 1 \le i \le n\} \cup \{w_i : 1 \le i \le n\} \cup \{e_i : 1 \le i \le n\} \cup \{e'_i : 1 \le i \le n\}$.
Thus we have $\chi_r(T(K_{1,n,n})) \ge n + 1$.

Case 1: For $1 \le r \le n$
Consider the color class $C_1 = \{c_1, c_2, c_3, .., c_{(n+1)}\}$
Assign the r-dynamic coloring to $T(K_{1,n,n})$ by algorithm 2.3.1
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Thus we have $\chi_r(T(K_{1,n,n})) = n + 1$ if $1 \le r \le n$.

Case 2: For $n + 1 \le r \le \Delta - 2$
Consider the color class $C_2 = \{c_1, c_2, c_3, .., c_{(2n-1)}\}$
Assign the r-dynamic coloring to $T(K_{1,n,n})$ by algorithm 2.3.2
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(T(K_{1,n,n})) = r + 1$ if $n + 1 \le r \le \Delta - 2$.

Case 3: For $r = \Delta - 1$
Consider the color class $C_3 = \{c_1, c_2, c_3, .., c_{2n}\}$
Assign the r-dynamic coloring to $T(K_{1,n,n})$ by algorithm 2.3.3
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(T(K_{1,n,n})) = 2n$ if $r = \Delta - 1$.

Case 4: For $r = \Delta$
Consider the color class $C_4 = \{c_1, c_2, c_3, .., c_{2n+1}\}$
Assign the r-dynamic coloring to $T(K_{1,n,n})$ if $r = \Delta$ by algorithm 2.3.4
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(T(K_{1,n,n})) = 2n + 1$ if $r \ge \Delta$.

□

Algorithm 2.3.1
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $T(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;

$C(e_i) = i;$
}
$V_2 = \{v\};$
$C(v) = n + 1;$
for $i = 1$ to $n - 1$
{
$V_3 = \{v_i\};$
$C(v_i) = i + 1;$
}
$C(v_n) = 1;$
for $i = 1$ to $n - 2$
{
$V_4 = \{e'_i\};$
$C(e'_i) = i + 2;$
}
$C(e'_{n-1}) = 1;$
$C(e'_n) = 2;$
for $i = 1$ to $n - 3$
{
$V_5 = \{w_i\};$
$C(w_i) = i + 3;$
}
$C(w_{n-2}) = 1;$
$C(w_{n-1}) = 2;$
$C(w_n) = 3;$
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5;$
end
Algorithm 2.3.2
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $T(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\};$
$C(e_i) = i;$
}
$V_2 = \{v\};$
$C(v) = n + 1;$
for $i = 1$ to $n - 3$
{
$V_3 = \{v_i\};$
$C(v_i) = r + 1;$
}
$C(v_{n-2}) = n + 2;$
$C(v_{n-1}) = n + 3;$
$C(v_n) = n + 4;$
for $i = 1$ to $n - 2$
{
$V_4 = \{e'_i\};$
$C(e'_i) = n + i + 2;$
}
$C(e'_{n-1}) = n + 2;$
$C(e'_n) = n + 3;$
for $i = 1$ to $n - 1$
{
$V_5 = \{w_i\};$
$C(w_i) = i + 1;$

}
$C(w_n) = 1;$
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5;$
end
Algorithm 2.3.3
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $T(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\};$
$C(e_i) = i;$
}
$V_2 = \{v\};$
$C(v) = n + 1;$
for $i = 1$ to $n - 1$
{
$V_3 = \{v_i\};$
$C(v_i) = n + i + 1;$
}
$C(v_n) = n + 2;$
for $i = 1$ to $n - 2$
{
$V_4 = \{e'_i\};$
$C(e'_i) = n + i + 2;$
}
$C(e'_{n-1}) = n + 2;$
$C(e'_n) = n + 3;$
for $i = 1$ to $n - 1$
{
$V_5 = \{w_i\};$
$C(w_i) = i + 1;$
}
$C(w_n) = 1;$
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5;$
end
Algorithm 2.3.4
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $T(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\};$
$C(e_i) = i;$
}
$V_2 = \{v\};$
$C(v) = n + 1;$
for $i = 1$ to n
{
$V_3 = \{v_i\};$
$C(v_i) = n + i + 1;$
}
for $i = 1$ to $n - 1$
{
$V_4 = \{e'_i\};$
$C(e'_i) = n + i + 2;$
}

$C(e'_n) = n + 3$;
for $i = 1$ to $n - 1$
{
$V_5 = \{w_i\}$;
$C(w_i) = i + 1$;
}
$C(w_n) = 1$;
$V = V_1 \cup V_2 \cup V_3 \cup V_4 \cup V_5$;
end

Theorem 2.4. *For any Double star graph $K_{1,n,n}$, the r-dynamic chromatic number*
$\chi_r(L(K_{1,n,n})) = \begin{cases} n, 1 \leq r \leq n-1 \\ n+1, r \geq \Delta \end{cases}$

Proof. First we apply the definition of Line graph on $K_{1,n,n}$

By the definition of line graph, each edge of $K_{1,n,n}$ taken to be as vertex in $L(K_{1,n,n})$.The vertices e_1, e_2, ..., e_n induce a clique of order n in $L(K_{1,n,n})$.
i.e., $V(L(K_{1,n,n})) = E(K_{1,n,n}) = \{e_i : 1 \leq i \leq n\} \cup \{w_i : 1 \leq i \leq n\}$.

Thus we have $\chi_r(L(K_{1,n,n})) \geq n$.

Case 1: For $(1 \leq i \leq \Delta - 1)$
Consider the vertex set $V(L(K_{1,n,n}))$ and color class $C_1 = \{c_1, c_2, ..., c_n\}$
Assign r dynamic coloring to $L(K_{1,n,n})$ by algorithm 2.4.1
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(L(K_{1,n,n})) = n$.
Case 2: For $(r \geq \Delta)$
Consider the vertex set $V(L(K_{1,n,n}))$ and color class $C_2 = \{c_1, c_2, ..., c_n, c_{(n+1)}\}$
Assign r dynamic coloring to $L(K_{1,n,n})$ by algorithm 2.4.2
Thus, an easy check shows that the $r-$ adjacency condition is fulfilled.
Hence $\chi_r(L(K_{1,n,n})) = n + 1$. □

Algorithm 2.4.1
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $L(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;
$C(e_i) = i$;
}
for $i = 1$ to $n - 1$
{
$V_2 = \{w_i\}$;
$C(w_i) = i + 1$;
}
$C(w_n) = 1$;
$V = V_1 \cup V_2$;
end
Algorithm 2.4.2
Input: The number "n" of $K_{1,n,n}$.
Output: Assigning r-dynamic coloring for the vertices in $L(K_{1,n,n})$.
begin
for $i = 1$ to n
{
$V_1 = \{e_i\}$;

$C(e_i) = i;$
}
for $i = 1$ to n
{
$V_2 = \{w_i\};$
$C(w_i) = n + 1;$
}
$V = V_1 \cup V_2;$
end

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Received: February 7, 2019.
Accepted: July 14, 2019