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Radio 1 - Chromatic Number of Uniform r - Cyclic Split Graph and n -Wheel Star Graph

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ABSTRACT: For any integer k , lies between zero and diameter plus one, a radio k -chromatic labelling of a simple connected graph $G = (V, E)$ is a mapping from $V(G)$ to \mathbb{N} such that $d(u, v) + |g(u) - g(v)| \geq 1 + k$, $\forall u, v \in V(G)$, where $d(u, v)$ is the distance between u and w . The maximum number assigned to a vertex under the mapping h is denoted by $r_{ck}(g)$, is called the radio k - chromatic number of G under the mapping g . The radio k - chromatic number of G , denoted by $r_{ck}(G)$ is the minimum value taken over all such radio k - chromatic numbers of g . In this paper, we have obtained the radio 1 -chromatic number of Uniform r - cyclic split graph and n -wheel star graph.

KEYWORDS: labelling, radio k -chromatic number, uniform r -cyclic split graph, n -wheel star graph.

I. INTRODUCTION

In order to find the maximum number of channels in a predetermined electromagnetic spectrum bandwidth, in 2004, Chartrand et.al. [11] introduces the concept of radio k -chromatic number. The graph theoretical definition is given as follows: For any integer k , lies between zero and diameter plus one, a radio k -chromatic labelling of a simple connected graph $G = (V, E)$ is a mapping from $V(G)$ to \mathbb{N} such that $d(u, v) + |g(u) - g(v)| \geq 1 + k$, $\forall u, v \in V(G)$ where $d(u, v)$ is the distance between u and w . The maximum number assigned to a vertex under the mapping h is denoted by $r_{ck}(g)$, is called the radio k -chromatic number of G under the mapping g . The radio k -chromatic number of G , denoted by $r_{ck}(G)$ is the minimum value taken over all such radio k -chromatic numbers of g .

Based on various values of k , the problem is classified as follows: When $k = 1$, the radio 1-chromatic number is same as the ordinary chromatic number problem and it was studied in [7,13]. If $k = 2$, the radio 2-chromatic number is equivalent to distance two problem or $L(2,1)$ - labelling number. This problem is widely studied by several authors [4, 8, 9,10,15, 16, 17, 18, 22, 23, 24, 31]. When $k = rad(G)$, where $rad(G)$ is the radius of the graph, then the problem is called radial radio number and it has been studied by only few researchers [1, 3, 21, 26, 32, 35]. If we replace k by $diam(G) - 1$, where $diam(G)$ is the diameter of the graph G , then the problem was named as radio antipodal number. Few results related to this problem can be seen in the articles [2, 9, 10, 14, 19, 20]. When $k = diam(G)$, then the problem is called radio number problem which is used to find the maximum number of channels for FM radio stations. Many research articles [5, 6, 12, 25, 27, 28, 29, 30, 33, 34, 36, 37] in this area has been published. In this paper, we have completely determined the chromatic number of uniform r -cyclic split graph and n -wheel star graph.

II. UNIFORM r - CYCLIC SPLIT GRAPH $KC(r)$

In this section, we have investigated the radio 1-chromatic number of Uniform r - cyclic split graph $KC(r)$ and n -wheel star graph

The following graph is introduced by Bharati et.al. [5]. The following definition of $KC(r)$ is taken from [28].

Definition 2.1: A uniform r -cyclic split graph represented by $KC(r)$ is a graph in which the removal of nmr edges in $KC(r)$ partition the graph into nm independent cycles of length r and a complete K_n . If each of the nm cycles of length r is shrunk to a vertex, then the uniform r -cyclic split graph reduces to the standard split graph. Further, at each

vertex of the complete graph, there are k wheels attached. The number of edges and vertices are $2nmr + \frac{n(n-1)}{2}$ and $n(mr + 1)$ respectively.

Theorem 2.1: Let r be even, then the chromatic number uniform r -cyclic split graph $KC(r)$ is $rc_1(KC(r)) = n + 2$.

Proof: Before assign the chromatic labelling, first we name the vertices of the complete graph K_n as $\{w_1, w_2 \dots w_n\}$ and the nm cycles as $\{v_1, v_2 \dots v_r, v_{r+1} \dots v_{mr}, v_{mr+1} \dots v_{nmr}\}$ respectively. Next, we define a mapping g from $V(KC(r))$ to the positive integers as follows:

$$g(v_{\sigma}) = \begin{cases} 1, & \text{if } \sigma \text{ is odd} \\ 2, & \text{if } \sigma \text{ is even} \end{cases}, \sigma = 1, 2 \dots nmr.$$

$$g(w_{\sigma}) = 2 + \sigma, \sigma = 1, 2 \dots n.$$

Claim: $d(u, v) + |g(u) - g(v)| \geq 2$, for all $u, v \in V(KC(r))$.

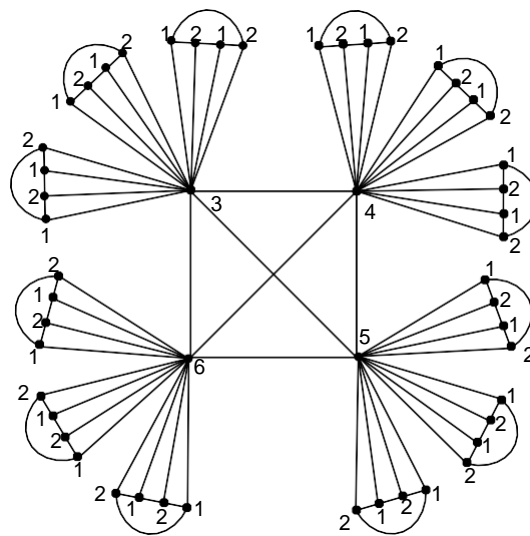


Figure 1: A chromatic labelling of $KC(r)$ with $r = n = 4, m = 3$.

Case 1: Let u and v any two arbitrary vertices be vertices on cycle, then by the naming of vertices, u and v are takes the form $u = v_{\sigma}$ and $v = v_{\underline{\sigma}}$, $1 \leq \sigma \neq \underline{\sigma} \leq nmr$.

Case 1.1: Suppose both σ and $\underline{\sigma}$ are odd, then from the above defined mapping $g(v_{\sigma}) = 1 = g(v_{\underline{\sigma}})$. Also, $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 2$. Hence the radio 1-chromatic condition becomes $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2 + |0| \geq 2$.

Case 1.2: Suppose both σ and $\underline{\sigma}$ are even, then from the above mapping $g(v_{\sigma}) = 2 = g(v_{\underline{\sigma}}) = 2$. Also, $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 2$. Therefore, labelling condition becomes $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2 + |0| \geq 2$.

Case 1.3: If σ is odd and $\underline{\sigma}$ is even, then $g(v_{\sigma}) = 1$ and $g(v_{\underline{\sigma}}) = 2$. In addition, $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 1$. Hence, the radio 1-chromatic condition becomes $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 1 + |1 - 2| \geq 2$.

Case 1.4: If σ is even and $\underline{\sigma}$ is odd, then $g(v_{\sigma}) = 2$ and $g(v_{\underline{\sigma}}) = 1$. In this subcase also $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 1$. Therefore, $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 1 + |2 - 1| \geq 2$.

Case 2: Suppose both the vertices are complete graph vertices, then, u and v are takes the form $u = w_{\sigma}$ and $v = w_{\underline{\sigma}}$, $1 \leq \sigma \neq \underline{\sigma} \leq n$. Then from the above defined mapping $g(w_{\sigma}) = \sigma + 2$ and $g(w_{\underline{\sigma}}) = \underline{\sigma} + 2$ respectively. Also, $d(v_{\sigma}, v_{\underline{\sigma}}) = 1$. Hence, the radio 1-chromatic condition becomes $d(w_{\sigma}, w_{\underline{\sigma}}) + |g(w_{\sigma}) - g(w_{\underline{\sigma}})| \geq 1 + |\sigma + 2 - (\underline{\sigma} + 2)| \geq 1 + |\sigma - \underline{\sigma}| \geq 2$. Since, $\sigma \neq \underline{\sigma}$.

Case 3: Suppose u on the cycle and v is a complete graph vertex then $u = v_{\sigma}$, $1 \leq \sigma \neq \underline{\sigma} \leq nmr$ and $v = w_{\underline{\sigma}}$, $1 \leq \underline{\sigma} \leq n$. Therefore, in this case the distance between v_{σ} and $w_{\underline{\sigma}}$ is either 1 or 2. In addition, the $|g(u) - g(w)| \geq |(2 - (2 + \underline{\sigma}))| \geq \underline{\sigma}$. Hence, $d(v_{\sigma}, w_{\underline{\sigma}}) + |g(v_{\sigma}) - g(w_{\underline{\sigma}})| \geq 1 + \underline{\sigma} \geq 2$, since $\underline{\sigma} > 0$.

Thus, the radio 1-chromatic condition is satisfied for every pair of vertices in $V(KC(r))$.

Hence the given mapping yields the result, $rc_1(KC(r)) = n + 2$, whenever r is even.

Theorem 2.2: Let r be odd, then the chromatic number uniform r -cyclic split graph $KC(r)$ is $rc_1(KC(r)) = n + 3$.

Proof: Define a mapping g from $V(KC(r))$ to N as follows:

$$g(v_{\sigma}) = \begin{cases} 1, & \text{if } \sigma \text{ is odd and } \sigma \not\equiv 0 \pmod{r} \\ 2, & \text{if } \sigma \text{ is even, } \sigma = 1, 2 \dots nmr. \\ 3, & \text{if } \sigma \text{ is odd and } \sigma \equiv 0 \pmod{r} \end{cases}$$

$$g(w_{\sigma}) = 3 + \sigma, \sigma = 1, 2 \dots n.$$

Claim: $d(u, v) + |g(u) - g(v)| \geq 2$, for all $u, v \in V(KC(r))$.

Case 1: Let u and v any two arbitrary vertices be vertices on cycle, then by the naming of vertices, u and v are takes the form $u = v_{\sigma}$ and $v = v_{\underline{\sigma}}$, $1 \leq \sigma \neq \underline{\sigma} \leq nmr$.

Case 1.1: Suppose both σ and $\underline{\sigma}$ are odd and $\sigma, \underline{\sigma} \not\equiv 0 \pmod{r}$, then $g(v_{\sigma}) = 1 = g(v_{\underline{\sigma}})$ and $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 2$. Hence, the radio 1-chromatic condition becomes $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2 + |0| \geq 2$.

Case 1.2: Suppose both σ and $\underline{\sigma}$ are even, then the case is as same as Case 1.2.

Case 1.3: If σ is odd, $\sigma \not\equiv 0 \pmod{r}$ and $\underline{\sigma}$ is even, then $g(v_{\sigma}) = 1$ and $g(v_{\underline{\sigma}}) = 2$. In addition, $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 1$. Hence, the radio 1-chromatic condition becomes $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 1 + |1 - 2| \geq 2$.

Case 1.4: If σ is even and $\underline{\sigma}$ is odd, $\underline{\sigma} \not\equiv 0 \pmod{r}$, then the case is similar to Case 1.3.

Case 1.5: If σ is odd or even, $\sigma \not\equiv 0 \pmod{r}$ and $\underline{\sigma} \equiv 0 \pmod{r}$, then either $g(v_{\sigma}) = 1$ or 2 . Also, $g(v_{\underline{\sigma}}) = 3$ and $d(v_{\sigma}, v_{\underline{\sigma}}) \geq 1$. Hence, the radio 1-chromatic condition becomes $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2$.

$|g(u) - g(v)| \geq 2$, for all $u, v \in V(KC(r))$.

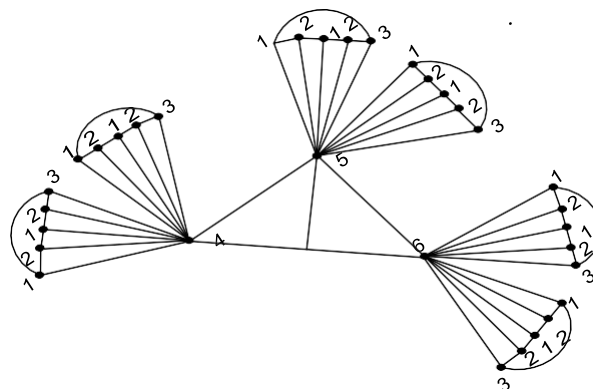


Figure 2: A chromatic labelling of $KC(r)$ with $n = 3, m = 3$ and $r = 5$.

Case 2: Suppose both the vertices are complete graph vertices, then, u and v are takes the form $u = w_{\sigma}$ and $v = w_{\underline{\sigma}}$, $1 \leq \sigma \neq \underline{\sigma} \leq n$. Then, $g(w_{\sigma}) = \sigma + 2$ and $g(w_{\underline{\sigma}}) = \underline{\sigma} + 3$ respectively. Also, $d(v_{\sigma}, v_{\underline{\sigma}}) = 1$. Hence, $d(w_{\sigma}, w_{\underline{\sigma}}) + |g(w_{\sigma}) - g(w_{\underline{\sigma}})| \geq 1 + |\sigma + 2 - (\underline{\sigma} + 3)| \geq 1 + |\sigma - \underline{\sigma}| \geq 2$. Since, $\sigma \neq \underline{\sigma}$.

Case 3: Suppose u on the cycle and v is a complete graph vertex then $u = v_{\sigma}$, $1 \leq \sigma \neq \underline{\sigma} \leq nmr$ and $v = w_{\underline{\sigma}}$, $1 \leq \underline{\sigma} \leq n$. Therefore, the distance between v_{σ} and $w_{\underline{\sigma}}$ is either 1, 2 or 3. Moreover,

$|g(v_{\sigma}) - g(w_{\underline{\sigma}})| \geq |3 - (3 + \underline{\sigma})| \geq \underline{\sigma}$. Hence, $d(v_{\sigma}, w_{\underline{\sigma}}) + |g(v_{\sigma}) - g(w_{\underline{\sigma}})| \geq 1 + \underline{\sigma} \geq 2$, since $\underline{\sigma} > 0$.

Thus, the radio 1-chromatic condition is also satisfied for every pair of vertices in $V(KC(r))$, r is odd. Hence the given mapping yields the result, $rc_1(KC(r)) = n + 3$, whenever r is odd.

III. n - WHEEL STAR GRAPH

In this subsection, we have determined the radio-1 chromatic number of n -wheel star graph. The following graph was introduced by Francis et.al. [15].

Definition 2.1: Let $v_i, 1 \leq i \leq n$ be the vertices of the star graph S_{n+1} with hub at x and let $u_i, 1 \leq i \leq nr$ be the vertices in the wheel graphs with hubs at $v_i, i = 1, 2 \dots n$. The graph obtained is termed as n -wheel star graph and it is

denoted by $WS(n, r)$. The cardinality of the vertex set and edge set of $WS(n, r)$ are $nr + n + 1$ and $nr + n$ respectively. We have obtained the results separately, for odd and even cases.

Theorem 3.1: Let r be even, then the chromatic number of n -wheel star graph $WS(n, r)$ is $rc_1(WS(n, r)) = 3$.

Proof: Define a mapping $g: WS(n, r) \rightarrow N$ as follows

$$g(u_{\sigma}) = \begin{cases} 2, & \text{if } \sigma \text{ is odd} \\ 3, & \text{if } \sigma \text{ is even} \end{cases}, \sigma = 1, 2 \dots nr.$$

$$g(v_{\sigma}) = 1, \sigma = 1, 2 \dots n.$$

$$g(x) = 2.$$

Next, we claim that $d(u, v) + |g(u) - g(v)| \geq 2$, for all $u, v \in V(WS(n, r))$.

Case 1: Let u and v any two arbitrary vertices on the star graph, then u and v takes the form $u = v_{\sigma}$ and $v = v_{\underline{\sigma}}$, $1 \leq \sigma \neq \underline{\sigma} \leq n$. In this case, v_{σ} and $v_{\underline{\sigma}}$ are labelled as 1. But the distance between them is just two. Consequently, $d(v_{\sigma}, v_{\underline{\sigma}}) + |g(v_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2$.

Case 2: Let $u = u_{\sigma}$ and $v = u_{\underline{\sigma}}$, $1 \leq \sigma \neq \underline{\sigma} \leq nr$.

Case 2.1: Suppose both σ and $\underline{\sigma}$ are odd number or an even number, then from the mapping $g(u_{\sigma}) = g(u_{\underline{\sigma}})$ and $d(u_{\sigma}, u_{\underline{\sigma}}) \geq 2$. Hence, $d(u_{\sigma}, u_{\underline{\sigma}}) + |g(u_{\sigma}) - g(u_{\underline{\sigma}})| \geq 2$.

Case 2.2: If $\sigma \in 2N + 1$ and $\underline{\sigma} \in 2N$ or $\sigma \in 2N$ and $\underline{\sigma} \in 2N + 1$ then $g(u_{\sigma}) = 2$ and $g(u_{\underline{\sigma}}) = 3$ or $g(u_{\sigma}) = 3$ and $g(u_{\underline{\sigma}}) = 2$. In these possibilities, $d(u_{\sigma}, u_{\underline{\sigma}}) \geq 1$. Hence, $d(u_{\sigma}, u_{\underline{\sigma}}) + |g(u_{\sigma}) - g(u_{\underline{\sigma}})|$ satisfies the required inequality.

Case 3: Assume $u = u_{\sigma}$, $1 \leq \sigma \leq nr$ and $v = v_{\underline{\sigma}}$, $1 \leq \underline{\sigma} \leq n$. Therefore, in this case the distance between u_{σ} and $v_{\underline{\sigma}}$ is atleast 1 and the modulus difference between the function values is exactly 1. Therefore, $d(u_{\sigma}, v_{\underline{\sigma}}) + |g(u_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2$.

Case 4: Finally, if we choose $u = x$ and v is any other vertex in the graph, then there are three possibilities arises. If v is an odd suffix vertex, then the distance between them is exactly 2. Also, if v is an even suffix vertex, then the distance between them is atleast 1 and $|g(u) - g(v)| = 1$. Otherwise the distance between is atleast 1 and the modulus difference between the function values is exactly 1. Therefore, $d(u_{\sigma}, v_{\underline{\sigma}}) + |g(u_{\sigma}) - g(v_{\underline{\sigma}})| \geq 2$.

Thus, the radio 1-chromatic condition is satisfied for every pair of vertices in $V(WS(n, r))$.

Hence, $rc_1(KC(r)) = 3, r$ is even.

Theorem 3.2: Let r be odd, then the chromatic number n -wheel star graph is $rc_1(WS(n, r)) = 4$.

Proof: Define a mapping g from $V(WS(n, r))$ to N as follows:

$$g(v_{\sigma}) = \begin{cases} 2, & \text{if } \sigma \text{ is odd and } \sigma \not\equiv 0 \pmod{r} \\ 3, & \text{if } \sigma \text{ is even, } \sigma = 1, 2 \dots nr \\ 4, & \text{if } \sigma \text{ is odd and } \sigma \equiv 0 \pmod{r} \end{cases}$$

$$g(v_{\sigma}) = 1, \sigma = 1, 2 \dots n.$$

$$g(x) = 2.$$

As the remaining part of the proof is similar to previous theorem, we left the proof.

IV. CONCLUSION

In this paper we have determined the 1-chromatic number of Uniform r -cyclic split graph and n -wheel star graph. Further, the research can be extended to study different k -values for interconnection networks.

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