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# SEVERAL RESULT ON SD-PRIME CORDIAL GRAPHS

S. JENIFER WENCY[1,*] AND A. LOURDUSAMY[2]

[1]Research Scholar, Department of Mathematics, Manonmaniam Sundaranar University, Tirunelveli, India

[2]Department of Mathematics, St. Xaviers College (Autonomous), Palayamkottai, Tamil Nadu, India



**Abstract.** A bijection $f : V(G) \to \{1, 2, \cdots, |V(G)|\}$ induces an edge labeling $f^* : E(G) \to \{0, 1\}$ such that for any edge $uv$ in $G$, $f^*(uv) = 1$ if $gcd(S, D) = 1$ and $f^*(uv) = 0$ otherwise, where $S = f(u) + f(v)$ and $D = |f(u) - f(v)|$. The labeling $f$ is called SD-prime cordial labeling if $|e_{f^*}(0) - e_{f^*}(1)| \leq 1$. We say that $G$ is SD-prime cordial graph if it admits SD-prime cordial labeling. In this paper, we prove that certain classes of zero-divisor graphs of commutative rings are SD-prime cordial graphs.

**Keywords:** zero-divisor graphs; SD-prime cordial labeling.

**2010 AMS Subject Classification:** 05C78.

## 1. Introduction

Let $G = (V(G), E(G))$ be a simple, finite and undirected graph with vertex set $V(G)$ and edge set $E(G)$. All notation not defined in this paper can be found in [4]. Graph labeling is currently an emerging area in the research of graph theory. A graph labeling is an assignment of integers to the vertices or edges or both subject to certain conditions. The concept of graceful labeling was introduced by Rosa [10] in 1960's. For an excellent survey of graph labeling, we refer the reader to Gallian [3]. Lau et al. have introduced the concepts SD-prime cordial labeling in

*Corresponding author
E-mail address: jeniferwency@gmail.com
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[5]. Further results on SD-prime cordial graphs were discussed in [6, 7, 8, 9]. The idea of a graph associated to zero-divisors of a commutative ring was introduced by I. Beck [2]. Later it was modified by D. F. Anderson and P. S. Livingston [1]. Let $R$ be a commutative ring with non-zero identity, $Z(R)$ its set of all zero-divisors in $R$ and $Z^*(R) = Z(R)\backslash\{0\}$. The zero-divisor graph of $R$ is the simple undirected graph $\Gamma(R)$ with vertex set $Z^*(R)$ and two distinct vertices $x$ and $y$ are adjacent if and only if $xy = 0$. The concept of the coloring of zero-divisor graphs of commutative ring was introduced by I. Beck [2]. Motivated by this, T. Tamizh Chelvam et al. [11] were introduced concept of the labeling of zero-divisor graphs of commutative ring. Also, they have proved that certain classes of zero-divisor graphs of commutative rings are sum cordial graphs. In this paper, we prove that certain classes of zero-divisor graphs are SD-prime cordial graphs.

## 2. Preliminaries

Given a bijection $f : V(G) \to \{1, 2, \cdots, |V(G)|\}$, we associate 2 integers $S = f(u) + f(v)$ and $D = |f(u) - f(v)|$ with every edge $uv$ in $E$.

**Definition 2.1.** [5] *A bijection $f : V(G) \to \{1, 2, \cdots, |V(G)|\}$ induces an edge labeling $f^* : E(G) \to \{0, 1\}$ such that for any edge $uv$ in $G$, $f^*(uv) = 1$ if $gcd(S, D) = 1$, and $f^*(uv) = 0$ otherwise. The labeling $f$ is called SD-prime cordial labeling if $|e_{f^*}(0) - e_{f^*}(1)| \leq 1$. We say that $G$ is SD-prime cordial graph if it admits SD-prime cordial labeling.*

**Definition 2.2.** *The join of two graphs $G_1$ and $G_2$ is denoted by $G_1 + G_2$ and whose vertex set is $V(G_1 + G_2) = V(G_1) \bigcup V(G_2)$ and edge set is $E(G_1 + G_2) = E(G_1) \bigcup E(G_2) \bigcup \{uv : u \in V(G_1), v \in V(G_2)\}$.*

**Definition 2.3.** *A bipartite graph is a graph whose vertex set $V(G)$ can be partitioned into two subsets $V_1$ and $V_2$ such that every edge of $G$ has one end in $V_1$ and the other end in $V_2$. $(V_1, V_2)$ is called a bipartition of $G$.*

**Definition 2.4.** *A complete bipartite graph is a bipartite graph with bipartition $(V_1, V_2)$ such that every vertex of $V_1$ is joined to all the vertices of $V_2$. It is denoted by $K_{m,n}$, where $|V_1| = m$ and $|V_2| = n$. A star graph is a complete bipartite graph $K_{1,n}$.*

**Definition 2.5.** *The complement $\overline{G}$ of the graph $G$ is the graph with vertex set $V(G)$ and two vertices are adjacent in $\overline{G}$ if and only if they are not adjacent in $G$.*

**Definition 2.6.** *The Cartesian product $G_1 \times G_2$ of two graphs is defined to be the graph with vertex set $V_1 \times V_2$ and two vertices $u = (u_1, u_2)$ and $v = (v_1, v_2)$ are adjacent in $G_1 \times G_2$ if either $u_1 = v_1$ and $u_2$ is adjacent to $v_2$ or $u_2 = v_2$ and $u_1$ is adjacent to $v_1$.*

## 3. MAIN RESULTS

**Theorem 3.1.** *Let $p$ be a prime number with $p > 2$ and $\Gamma(\mathbb{Z}_{2p})$ be the zero-divisor graph of the commutative ring $\mathbb{Z}_{2p}$. Then $\Gamma(\mathbb{Z}_{2p})$ is SD-prime cordial graph.*

*Proof.* Let $p$ be a prime number and $p > 2$. Then the vertex set of $\Gamma(\mathbb{Z}_{2p})$ is $Z^*(\mathbb{Z}_{2p}) = \{2, 4, \ldots, 2(p-1), p\} = \{v_1, \ldots, v_{p-1}, v_p\}$ and the edge set of $\Gamma(\mathbb{Z}_{2p})$ is $E(\Gamma(\mathbb{Z}_{2p})) = \{v_i v_p : 1 \leq i \leq p-1\}$. Therefore, $\left|Z^*(\mathbb{Z}_{2p})\right| = p$ and $\left|E(\Gamma(\mathbb{Z}_{2p}))\right| = p-1$. We define $f : V(\Gamma(\mathbb{Z}_{2p})) \to \{1, 2, 3, \ldots, p\}$ by $f(v_i) = i+1$ for $1 \leq i \leq p-1$ and $f(v_p) = 1$. Here we have $e_{f^*}(0) = e_{f^*}(1) = \frac{p-1}{2}$. Hence $\Gamma(\mathbb{Z}_{2p})$ is SD-prime cordial graph for $p$ is a prime number and $p > 2$. $\square$

**Theorem 3.2.** *Let $p$ be a prime number with $p \geq 2$ and $\Gamma(\mathbb{Z}_{3p})$ be the zero-divisor graph of the commutative ring $\mathbb{Z}_{3p}$. Then $\Gamma(\mathbb{Z}_{3p})$ is SD-prime cordial graph.*

*Proof.* If $p = 2$ then $\Gamma(\mathbb{Z}_6)$. Therefore, $Z^*(\mathbb{Z}_6) = \{2, 3, 4\}$ and $\Gamma(\mathbb{Z}_6)$ being a path on three vertices is obviously SD-prime cordial graph.

If $p = 3$ then $\Gamma(\mathbb{Z}_9)$. Therefore, $Z^*(\mathbb{Z}_9) = \{3, 6\}$ and $\Gamma(\mathbb{Z}_9)$ being a path on two vertices is obviously SD-prime cordial graph.

Let $\Gamma(\mathbb{Z}_{3p})$ be a zero-divisor graph of $\mathbb{Z}_{3p}$, where $p$ is a prime number and $p > 3$. Then the vertex set of $\Gamma(\mathbb{Z}_{3p})$ is $Z^*(\mathbb{Z}_{3p}) = \{p, 2p\} \bigcup \{3, 6, \ldots, 3(p-1)\} = \{u_1, u_2\} \bigcup \{v_1, \ldots, v_{p-1}\}$ and the edge set of $\Gamma(\mathbb{Z}_{3p})$ is $E(\Gamma(\mathbb{Z}_{3p})) = \{u_1 v_i, u_2 v_i : 1 \leq i \leq p-1\}$. Therefore, $\left|Z^*(\mathbb{Z}_{3p})\right| = p+1$ and $\left|E(\Gamma(\mathbb{Z}_{3p}))\right| = 2p-2$. We define the labeling $f : V(\Gamma(\mathbb{Z}_{3p})) \to \{1, 2, 3, \ldots p+1\}$ as follows: $f(u_1) = 1$, $f(u_2) = 2$ and $f(v_i) = i+2$ for $1 \leq i \leq p-1$. Here we have $e_{f^*}(0) = p-1$ and $e_{f^*}(1) = p-1$. Hence $\Gamma(\mathbb{Z}_{3p})$ is SD-prime cordial graph. $\square$

**Theorem 3.3.** *Let $p$ be a prime number with $p \geq 2$ and $\Gamma(\mathbb{Z}_{4p})$ be the zero-divisor graph of the commutative ring $\mathbb{Z}_{4p}$. Then $\Gamma(\mathbb{Z}_{4p})$ is SD-prime cordial graph.*

*Proof.* If $p=2$ then $\Gamma(\mathbb{Z}_8)$. Therefore, $Z^*(\mathbb{Z}_8)=\{2,4,6\}$ and $\Gamma(\mathbb{Z}_8)$ being a path on three vertices is obviously SD-prime cordial graph.

Let $\Gamma(\mathbb{Z}_{4p})$ be a zero-divisor graph of $\mathbb{Z}_{4p}$, where $p$ is a prime number and $p\geq 3$. Here the vertex set of $\Gamma(\mathbb{Z}_{4p})$ is partitioned into two sets $V_1$ and $V_2$, where $V_1=\{p,2p,3p\}=\{u_1,u_2,u_3\}$ and $V_2=\{2,4,\ldots,2(p-1),2(p+1),\ldots,2(2p-1)\}=\{v_1,v_2,\ldots,v_{p-1},v_{p+1},\ldots,v_{2p-1}\}$ and the edge set of $\Gamma(\mathbb{Z}_{4p})$ is $E(\Gamma(\mathbb{Z}_{4p}))=\{u_1v_2,u_1v_4,\ldots,u_1v_{p-1},u_1v_{p+1},\ldots,u_1v_{2p-2},u_2v_1,u_2v_2,$ $u_2v_3,\ldots,u_2v_{p-1},\, u_2v_{p+1},\ldots,u_2v_{2p-1},u_3v_2,u_3v_4,\ldots,u_3v_{p-1},u_3v_{p+1},\ldots,u_3v_{2p-2}\}$. Therefore, $|Z^*(\mathbb{Z}_{4p})|=2p+1$ and $|E(\Gamma(\mathbb{Z}_{4p}))|=4p-4$. We define $f:V(\Gamma(\mathbb{Z}_{4p}))\to\{1,2,3,\ldots,2p+1\}$ is as follows: $f(u_1)=1$; $f(u_2)=2$; $f(u_3)=t$, where $t$ be a largest prime number $\leq 2p+1$; $f(v_j)=j+2$ for $1\leq j\leq p-1$; $f(v_j)=j+1$ for $p+1\leq j\leq t-2$ and

$$f(v_j)=\begin{cases} j+3 & \text{if } j \text{ is even and } t-2<j\leq 2p-1\\ j+1 & \text{if } j \text{ is odd and } t-2<j\leq 2p-1.\end{cases}$$

Here $e_{f^*}(0)=2p-2$ and $e_{f^*}(1)=2p-2$. Therefore $|e_{f^*}(0)-e_{f^*}(1)|\leq 1$. Hence $\Gamma(\mathbb{Z}_{4p})$ is SD-prime cordial graph. □

**Theorem 3.4.** *Let $p$ be a prime number with $p>2$ and $\Gamma(\mathbb{Z}_{2p})+\Gamma(\mathbb{Z}_4)$ be the zero-divisor graph of the commutative ring $\mathbb{Z}_{2p}+\mathbb{Z}_4$. Then $\Gamma(\mathbb{Z}_{2p})+\Gamma(\mathbb{Z}_4)$ is SD-prime cordial graph.*

*Proof.* Let $G=\Gamma(\mathbb{Z}_{2p})+\Gamma(\mathbb{Z}_4)$. Let $V(G)=\{2,4,\ldots,p-1,p\}\bigcup\{x: x=2\in\mathbb{Z}_4\}=\{u_1,\ldots,u_p,x\}$ and $E(G)=\{u_iu_p,u_ix,u_px: 1\leq i\leq p-1\}$. Therefore, $|V(G)|=p+1$ and $|E(G)|=2p-1$. Define $f:V(G)\to\{1,2,3,\ldots,p+1\}$ by $f(u_p)=1$, $f(x)=2$ and $f(u_i)=i+2$ for $1\leq i\leq p-1$. Clearly $e_{f^*}(0)=p-1$ and $e_{f^*}(1)=p$ and $|e_{f^*}(0)-e_{f^*}(1)|\leq 1$. Hence $G$ is SD-prime cordial graph. □

**Theorem 3.5.** *Let $p$ be a prime number with $p>2$ and $\Gamma(\mathbb{Z}_{2p})+\Gamma(\mathbb{Z}_9)$ be the zero-divisor graph of the commutative ring $\mathbb{Z}_{2p}+\mathbb{Z}_9$. Then $\Gamma(\mathbb{Z}_{2p})+\Gamma(\mathbb{Z}_9)$ is SD-prime cordial graph.*

*Proof.* Let $G=\Gamma(\mathbb{Z}_{2p})+\Gamma(\mathbb{Z}_9)$. Let $V(G)=\{2,4,\ldots,2(p-1),p\}\bigcup\{x,y: x=3,y=6\in\mathbb{Z}_9\}=\{u_1,\ldots,u_p,x,y\}$ and $E(G)=\{u_iu_p,u_ix,u_iy,u_px,u_py,xy: 1\leq i\leq p-1\}$. Therefore, $|V(G)|=p+2$ and $|E(G)|=3p$. We define the vertex labeling $f:V(G)\to\{1,2,3,\ldots,p+2\}$ is as follows: $f(x)=1$; $f(y)=2$; $f(u_p)=t$, where $t$ be a largest prime number $\leq p+2$; $f(u_i)=i+2$ for $1\leq i\leq t-3$ and

$$f(u_i) = \begin{cases} i+4 & \text{if } i \text{ is odd and } t-3 < i \leq p-1 \\ i+2 & \text{if } i \text{ is even and } t-3 < i \leq p-1. \end{cases}$$

Clearly, $e_{f^*}(0) = \frac{3p-1}{2}$ and $e_{f^*}(1) = \frac{3p+1}{2}$ and $|e_{f^*}(0) - e_{f^*}(1)| \leq 1$. Hence $\Gamma(\mathbb{Z}_{2p}) + \Gamma(\mathbb{Z}_9)$ is SD-prime cordial graph. □

**Corollary 3.6.** *Let $p$ be a prime number with $p > 2$ and $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_4)$ be the zero-divisor graph of the commutative ring $\overline{\mathbb{Z}_{p^2}} + \mathbb{Z}_4$. Then $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_4)$ is SD-prime cordial graph.*

*Proof.* Since the graph $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_4) \cong \Gamma(\mathbb{Z}_{2p})$, by Theorem 3.1, $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_4)$ is SD-prime cordial graph. □

**Theorem 3.7.** *Let $p$ be a prime number with $p > 2$ and $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_6)$ be the zero-divisor graph of the commutative ring $\overline{\mathbb{Z}_{p^2}} + \mathbb{Z}_6$. Then $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_6)$ is SD-prime cordial graph.*

*Proof.* Let $G = \overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_6)$. Let $V(G) = \{u_1, \ldots, u_{p-1}\} \bigcup \{x, y, z : x = 2, y = 3, z = 4 \in \mathbb{Z}_6\} = \{u_1, \ldots, u_{p-1}, x, y, z\}$ and $E(G) = \{u_i x, u_i y, u_i z, xy, yz : 1 \leq i \leq p-1\}$. Therefore, $|V(G)| = p+2$ and $|E(G)| = 3p-1$. Define the vertex labeling $f : V(G) \to \{1, 2, \ldots, p+2\}$ by $f(x) = 1$; $f(z) = 2$; $f(y) = t$, where $t$ be largest prime number $\leq p+2$; $f(u_i) = i+2$ for $1 \leq i \leq t-3$ and

$$f(u_i) = \begin{cases} i+4 & \text{if } i \text{ is odd and } t-3 < i \leq p-1 \\ i+2 & \text{if } i \text{ is even and } t-3 < i \leq p-1. \end{cases}$$

Here we have $e_{f^*}(0) = \frac{3p-1}{2}$ and $e_{f^*}(1) = \frac{3p-1}{2}$. Thus $|e_{f^*}(0) - e_{f^*}(1)| \leq 1$. Hence $G$ is SD-prime cordial graph. □

**Theorem 3.8.** *Let $p$ be a prime number with $p > 2$ and $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_9)$ be the zero-divisor graph of the commutative ring $\overline{\mathbb{Z}_{p^2}} + \mathbb{Z}_9$. Then $\overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_9)$ is SD-prime cordial graph.*

*Proof.* Let $G = \overline{\Gamma(\mathbb{Z}_{p^2})} + \Gamma(\mathbb{Z}_9)$. Let $V(G) = \{u_1, \ldots, u_{p-1}\} \bigcup \{x, y : x = 3, y = 6 \in \mathbb{Z}_9\} = \{u_1, \ldots, u_{p-1}, x, y\}$ and $E(G) = \{u_i x, u_i y, xy : 1 \leq i \leq p-1\}$. Therefore, $|V(G)| = p+1$ and $|E(G)| = 2p-1$. Define the vertex labeling $f : V(G) \to \{1, 2, \ldots, p+1\}$ by $f(x) = 1$, $f(y) = 2$ and $f(u_i) = i+2$ for $1 \leq i \leq p-1$. Clearly $e_{f^*}(0) = p-1$ and $e_{f^*}(1) = p$. Therefore $\left|e_{f^*}(0) - e_{f^*}(1)\right| \leq 1$. Hence $G$ is SD-prime cordial graph. □

**Theorem 3.9.** *Let $p$ be a prime number with $p > 2$ and $\overline{\Gamma(\mathbb{Z}_{p^2})} + \overline{\Gamma(\mathbb{Z}_9)}$ be the zero-divisor graph of the commutative ring $\overline{\mathbb{Z}_{p^2}} + \overline{\mathbb{Z}_9}$. Then $\overline{\Gamma(\mathbb{Z}_{p^2})} + \overline{\Gamma(\mathbb{Z}_9)}$ is SD-prime cordial graph.*

*Proof.* Let $G = \overline{\Gamma(\mathbb{Z}_{p^2})} + \overline{\Gamma(\mathbb{Z}_9)}$. Let $V(G) = \{u_1, \dots, u_{p-1}\} \bigcup \{x, y : x = 3, y = 6 \in \overline{\mathbb{Z}_9}\} = \{u_1, \dots, u_{p-1}, x, y\}$ and $E(G) = \{u_i x, u_i y : 1 \le i \le p-1\}$. Therefore, $|V(G)| = p+1$ and $|E(G)| = 2p-2$. The labeling pattern is analogous to that of the Theorem 3.8. Clearly, $e_{f^*}(0) = p-1$ and $e_{f^*}(1) = p-1$. Thus $\left|e_{f^*}(0) - e_{f^*}(1)\right| \le 1$. Hence $G$ is SD-prime cordial graph. $\square$

**Theorem 3.10.** *Let $p$ be a prime number with $p > 2$ and $\overline{\Gamma(\mathbb{Z}_{p^2})} + \overline{\Gamma(\mathbb{Z}_6)}$ be the zero-divisor graph of the commutative ring $\overline{\mathbb{Z}_{p^2}} + \overline{\mathbb{Z}_6}$. Then $\overline{\Gamma(\mathbb{Z}_{p^2})} + \overline{\Gamma(\mathbb{Z}_6)}$ is SD-prime cordial graph.*

*Proof.* Let $G = \overline{\Gamma(\mathbb{Z}_{p^2})} + \overline{\Gamma(\mathbb{Z}_6)}$. Let $V(G) = \{u_1, \dots, u_{p-1}\} \bigcup \{x, y, z : x = 2, y = 3, z = 4 \in \overline{\mathbb{Z}_6}\} = \{u_1, \dots, u_{p-1}, x, y, z\}$ and $E(G) = \{u_i x, u_i y, u_i z : 1 \le i \le p-1\}$. Therefore, $|V(G)| = p+2$ and $|E(G)| = 3p-3$. The labeling pattern is analogous to that of the Theorem 3.7. Therefore, $e_{f^*}(0) = \frac{3p-3}{2}$ and $e_{f^*}(1) = \frac{3p-3}{2}$. Thus $|e_{f^*}(0) - e_{f^*}(1)| \le 1$. Hence $G$ is SD-prime cordial graph. $\square$

**Theorem 3.11.** *Let $p$ be a prime number with $p > 2$ and $\Gamma(\mathbb{Z}_{2p}) + \overline{\Gamma(\mathbb{Z}_9)}$ be the zero divisor graph of the commutative ring $\mathbb{Z}_{2p} + \overline{\mathbb{Z}_9}$. Then $\Gamma(\mathbb{Z}_{2p}) + \overline{\Gamma(\mathbb{Z}_9)}$ is SD-prime cordial graph.*

*Proof.* Let $G = \Gamma(\mathbb{Z}_{2p}) + \overline{\Gamma(\mathbb{Z}_9)}$. Let $V(G) = \{2, 4, \dots, 2(p-1), p\} \bigcup \{x, y : x = 3, y = 6 \in \overline{\mathbb{Z}_9}\} = \{u_1, \dots, u_p, x, y\}$ and $E(G) = \{u_i u_p, u_i x, u_i y, u_p x, u_p y : 1 \le i \le p-1\}$. Therefore, $|V(G)| = p+2$ and $|E(G)| = 3p-1$. The labeling pattern is same as in the Theorem 3.5. From the labeling, we get $e_{f^*}(0) = \frac{3p-1}{2}$ and $e_{f^*}(1) = \frac{3p-1}{2}$ and also $|e_{f^*}(0) - e_{f^*}(1)| \le 1$. Hence $\Gamma(\mathbb{Z}_{2p}) + \overline{\Gamma(\mathbb{Z}_9)}$ is SD-prime cordial graph. $\square$

**Theorem 3.12.** *Let $p$ be a prime number with $p > 2$ and $\Gamma(\mathbb{Z}_{2p}) \times \Gamma(\mathbb{Z}_4)$ be the zero-divisor graph of the commutative ring $\mathbb{Z}_{2p} \times \mathbb{Z}_4$. Then $\Gamma(\mathbb{Z}_{2p}) \times \Gamma(\mathbb{Z}_4)$ is SD-prime cordial graph.*

*Proof.* Since the graph $\Gamma(\mathbb{Z}_{2p}) \times \Gamma(\mathbb{Z}_4) \cong \Gamma(\mathbb{Z}_{2p})$, by Theorem 3.1, $\Gamma(\mathbb{Z}_{2p}) \times \Gamma(\mathbb{Z}_4)$ is SD-prime cordial graph. $\square$

## CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

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