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Improving Lifetimein Wireless Sensor Networks Using GMD Mathematical model analysis

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Abstract
A Grid Mediation Device (GMD) mechanism and mathematical model are efficient methods that combined to enable the Cluster head (CH) to remain in sleep mode when no data must be sent in wireless sensor network. Results reveal that the proposed protocol prolongs lifetime by 100%. A mathematical model is adopted to assess the energy saved using the proposed protocol compared with that using Two- Dimensional Technique Based On Center Of Gravity And Energy Center In Wireless Sensor Network (TDTCGE) protocol. Furthermore, when the CH is in sleep mode for a long time, a substantial amount of energy can be saved. The GMD proposed protocol comprises a dynamic mechanism with a robust mathematical analysis that outperforms numerous earlier protocols. Many comparisons show that GMD Mathematical Model improves lifetime for the overall of Wireless sensor networks (WSNs). The proposed Mathematical Model that improve the lifetime 90% over TDTCGE protocol. The Proposed GMD Mathematical Model evaluated the performance of the proposed protocol through simulation based on a number of nodes and rounds.
Keywords: *wakeup, sleep, lifetime, energy saving, WSN.*

I. Introduction

WSNs have many applications according to the type of sensors installed. Examples of such applications include disaster relief, precision agriculture, and medical and health care. A WSN is crucial for gathering information necessary for smart devices that are part of pervasive computing (pervasive sensor networks), which is utilized in buildings, homes, transportation, or industrial systems. A pervasive sensor network consists of individual nodes (sensors) that can interact with the environment by sensing certain physical parameters. All sensor nodes generally have the same task (goal). To complete their tasks, a collaboration among these nodes is required. Given that sink nodes can be outside the network occasionally, the data collected by sensors are transmitted to sink nodes that are part of the network. Sensors and sinks exchange packets through wireless communication.

Nodes cannot be connected easily to a wired power supply in many WSN applications as they depend on onboard batteries instead [2]. In such cases, energy efficiency of communication protocols is a crucial concern (i.e., figure of merit) because extended operation time is necessary. As power supply may not be a problem in other applications, other metrics (e.g., accuracy of the delivered results) may be more relevant than energy efficiency.

A sensor is equipped with a radio transceiver or another wireless communication device that transmits and receives data over a wireless channel. A sensor also has a controller for manipulating data and memory for storing software and temporary data. A sensor commonly uses a battery as energy source.

The concept of WSNs is based on a simple equation [3]:

Sensing + CPU + Radio = many applications. However, to create an effective WSN, the combination of sensors, radio, and CPU warrants in-depth understanding of the capabilities and limitations of hardware components and networking. Sensor networks face several problems that may not occur in other types of networks. Power constraint is a major concern. Communication is the most energy-intensive task a node performs. Nodes must compete for a share of the limited bandwidth available. Networking protocols attempt to reduce energy consumption through two means; some communication tasks are neglected or the radio transceiver is turned off when communications are unnecessary [1].

WSNs combine the latest advances in low- power micro-sensors and short-range wireless radios to develop a sensational new technology. WSNs enable a number of sensing and monitoring services in vital areas such as industry production, safety and security at home and in traffic, and environmental monitoring.

The proposed protocol is compared with two protocols.

• Two-dimensional Technique based on Center of Gravity and Energy (TDTCGE) [7]

This protocol uses two-dimensional techniques. The center of gravity and energy for each grid are computed. The optimal node is selected as the CH as this node is the nearest to one of the centers. The TDTCGE protocol addresses the distance problem, particularly the distance of the CH from the BS. However, the problem of idle listening is overlooked. The results of this protocol demonstrate that both lifetime and energy consumption are enhanced.

II. Abbreviations and notations of Mathematical Model

In this section, the details of the network model and assumptions, the energy model, the link cost function and routing algorithm of the proposed protocol are provided. The CH remains in sleep mode for a long time if few cluster nodes have data to send during their Time Division Multiple Access (TDMA) turn. The generated formula of energy saved by the proposed protocol is defined as follows:

2.1 Network model

In this study, N sensor nodes are randomly deployed in a monitored environment. The sensor network has the following characteristics:

(1) The position of the base station (BS) in the sensor network is fixed.

(2) All nodes are heterogeneous and stationary, and their initial energy varies.

(3) All the nodes are randomly deployed in the target area, and they can connect with the BS.

2.2 Energy consumption

For comparison, this study adopts the first order radio model [20] to calculate hardware energy dissipation. The energy consumption of radio dissipation when sending and receiving data are both expressed as *Eelec*. The free space and multi-path fading channel models with amplifying index εfs and εamp are also employed. EDA denotes the energy consumption of data fusion. The energy spent by a node that transmits *L*-bits packet over distance *d* is related to the Heinzelman model. According to the Heinzelman model, each node consumes *Et* energy when transmitting *L* bits of data in distance *d*.

$$Et = L * Eelect + L * \in mp * d4 \quad d \geq d0. \quad (1)$$

else

$$Et = L * Eelect + L * \in fs * d2 \quad d < d0 \quad (2)$$

The energy required to receive *L* bits of data equals

$$Er = L * Eelec. \quad (3)$$

Parameters:

*d*0: crossover distance

Eelec: energy necessary for activating electronic circuits

∈*mp*, ∈f *s*: sensitivity and noise in the receiver, respectively

III. Mathematical Model Analysis

The CH and the nodes within each cluster are in sleep mode most of the time, and thus much power is saved (see Fig. 3). The three following equations, defined in [12], are used.

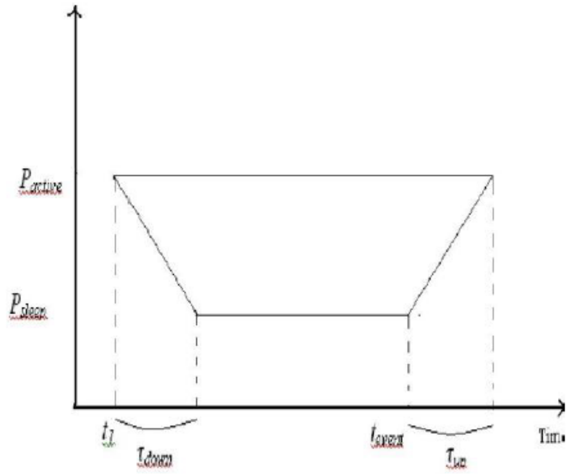

Fig. 6. Energy Conservation and Overhead for Sleep Modes

Whether or not a transceiver has to go into sleep mode to consume less power from

$P_{active}$to P_{sleep} is decided at time t_1 (see Fig. 7). If the transceiver remains active and the next event occurs at time t_{event}, then a total energy

of
$E_{TDTCGE} = P_{active} (t_{event} - t_1)$ **(1)**
is consumed. This formula can be applied to the CH in TDTCGE during the round when it is active because the transceiver of the cluster is always on in this round.
By contrast, putting the transceiver into sleep mode requires time τ_{down}until the sleep mode has been reached. The average power consumption during this phase is represented as

$(P_{active} + P_{slep})/2.$ **(2)**
In the proposed protocol, the CH is put tosleep for a part of this round. This formula represents the proposed protocol, which is ***Eactive - Esleep.***

Once a new data event occurs, an additional wake up overhead of
Ewakeupoverhead = up ((PaCtive + Pslep)/2)**(3)** is consumed during the transition from sleep mode.

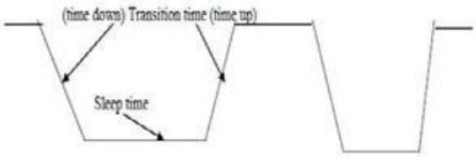

Fig.7. Sleep and Wake Up Cycle

The proposed protocol is similar to LEACH in the setup phase as both identify the CH and the nodes within the cluster. However, the proposed MD protocol varies from TDTCGE in the steady-state phase. The transition from active to sleep mode and vice versa requires a percentage of time, $_{trans}$ (e.g., 10% of round time). The CH is also in sleep mode for a fraction of time, $_{sleep}$ (e.g., 50% of round time).
The transition time from P_{active} to P_{sleep} is $_{down}$. On the basis of this assumption, we derive the following formula for saving energy:

Note that $\square_{trans} = \square_{up} = \square_{down}$.

$$E_{Proposed} = (t_{even}t - t_1)P_{active} - (\tau_{down}((P_{active} + P_{slep})/2) + (t_{event} - t_1 - \tau_{down}) P_{sleep}). \quad (4)$$

$$E_{proposed} = P_{active} - \square_{trans} (Pactive + Pslep)/2 - Esleep - \square_{sleep} * Psleep. \quad (5)$$

$$E_{proposed} = E_{Active} - E_{sleap} - E_{trans}. \quad (6)$$

$$E_{ToTAL} = E1 + E2 + E3 + E4 - E_{Proposed} . \quad (7)$$

The total amount of energy consumption of the entire network is equal to the following: E1: Energy to send information from each normal node to CH
E2: Energy consumed by CH to receive information from normal nodes
E3: Energy to gather information in CH
E4: Energy required to send information from CH to BS.

IV. Performance Metrics

The performance of the GMD proposed protocol can be evaluated with a number of metrics.
• **Network lifetime**: The time interval from the beginning of operation (of a sensor network) until the death of the last alive sensor.
• **First Dead Node (FDN):** Number of rounds after the first sensor died.

This parameter is directly related to the stability period parameter. A large FDN implies a long stability period of the network.
• **Last Dead Node (LDN):** Number of rounds after all sensor nodes are dead.

The proposed protocol is implemented using Matlab. Fig. 1 illustrates the number of grids with clusters. In each grid, one cluster comprises the MD node with CH and nodes.

Each grid appoints two dimensional points (center of gravity and energy). The results in Fig. 9 reveal that the lifetime extended by the proposed protocol is longer than that of the following protocols: TDTCGE, CRCWSN, Low-energy Adaptive Clustering Hierarchy(LEACH), Low-energy Adaptive Clustering Hierarchy with Sliding Window and Dynamic Number of Nodes (LEACH- SWDN) , Clustered Routing Protocol (ERP) , Stable Election Protocol (SEP) , and Energy- aware Evolutionary Routing Protocol (EAERP
) .

V. Simulation Results

Table 2. Research Parameters

Parameter	Value
Network size	100*100 m
Ee	50nJ/bit
Tevent_all (randi(9,1,m)+1)*1*10^{-3}m	
T	10
Pactive	6*10^{-3}mw
Tdown	1*10^{-3}m
Psleep	1*10^{-3}mw
L	1000 bit
Do	87m
Grids Number	4
Mp	0.0013 *10^{-9}
Fs	10*10^{-9}
Position BS	(75,125)
Number of nodes	100

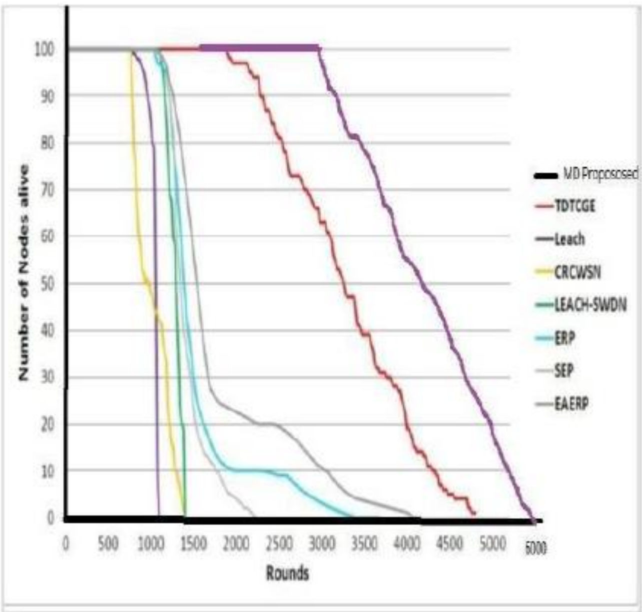

Fig. 8. Lifetime Extension per Protocol

The proposed GMD protocol extends the lifetime by 90% more than the TDTCGE. In the former, the first and last nodes die after 2300 and 6000 rounds, respectively; in the latter, the first and last nodes die after 1400 and 4880 rounds, respectively. Table 3 provides the results of FND and LND for the proposed protocol, TDTCGE, CRCWSN, LEACH, LEACH-SWDN, ERP, SEP, and EAERP.

Table 3. FND and LND for Each Protocol

Protocol	FND	LND
MD proposed	2300	6000
TDTCGE	1400	4880
CRCWSN	780	1400
LEACH	780	1100
LEACH-SWDN	1100	1490
ERP	1057	3673
SEP	1107	2238
EARP	1076	4085

When including time parameters to TDTCGE, the lifetime becomes different. The lifetime is reduced because the CH and nodes are constantly switched on, thus increasing the energy consumption (see Fig. 11).

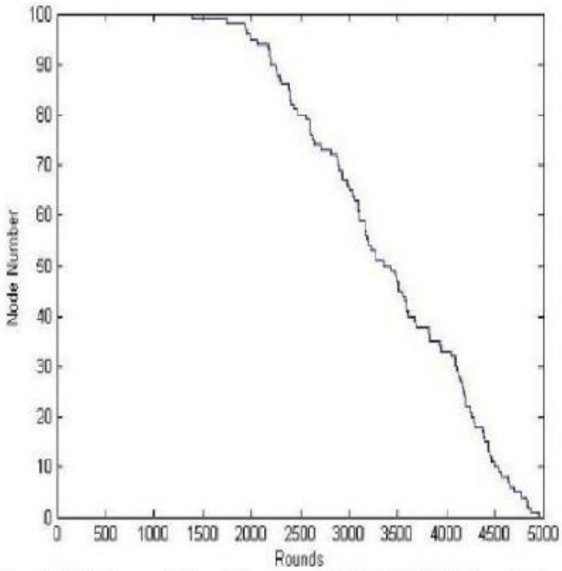

Fig. 9. Lifetime of the Original TDTCGE (WithoutTime Parameters)

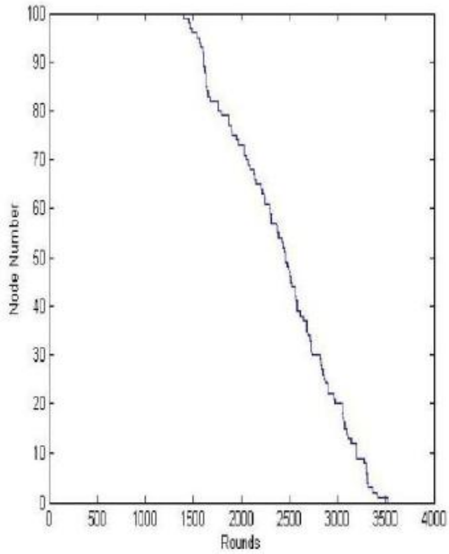

Fig. 10. Lifetime of the TDTCGE (With Time Parameters)

The time parameters are Initial Time*,* P_{active}, P_{sleep}, *Time down,* and *Time event*. The CH in TDTCGE remains on, so we include the time active parameter by adopting the formula $E_{TDTCGE} = P_{active} (t_{event} - t_1)$. The lifetime of TDTCGE with time parameters to be consumed is shorter than that without (see Figs. 10 and 11). In the former, the first and last nodes die at 1400 and 3600 rounds, respectively. In the latter, the first node dies at 1400 rounds as well. However, the LND value is 4880 rounds. The lifetime of TDTCGE without time parameters warrants an extended network lifetime compared with that with time parameters.

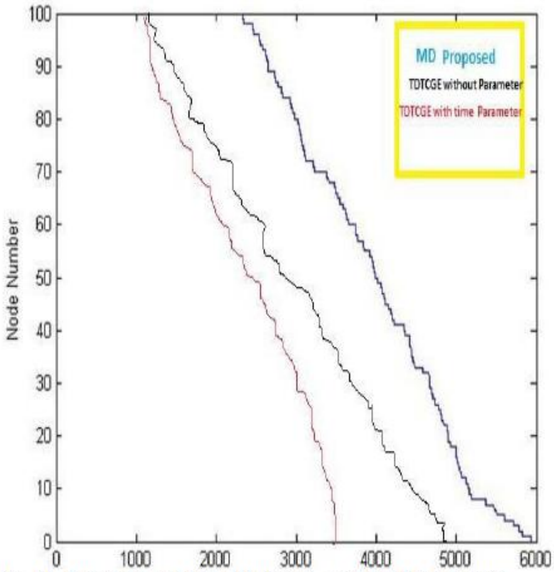

Fig. 11. Lifetime of MD, TDTCGE, and TDTCGE with Time Parameters

Fig. 12 illustrates that the lifetime of the MD proposed protocol exhibits 90% and 130% improvement compared with the original TDTCGE and TDTCGE with time parameters. The first and last nodes die at 2300 and 6000 rounds, respectively.

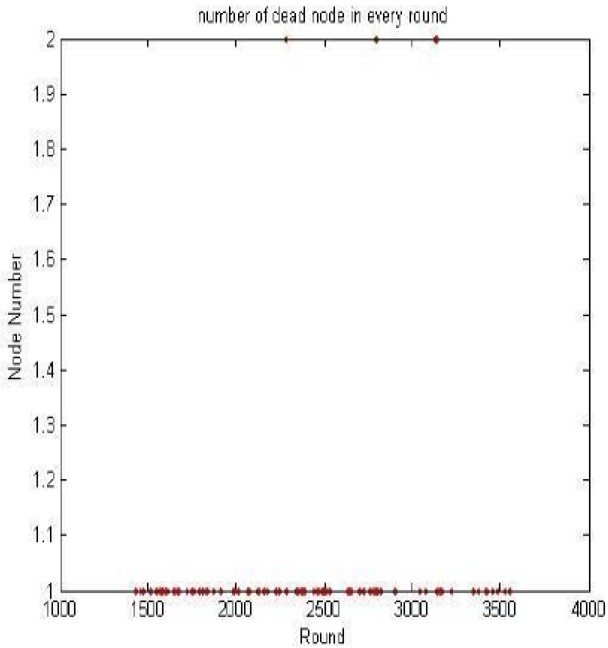

Fig. 12. Number of Dead Nodes in Each Round for TDTCGE with Time Parameters

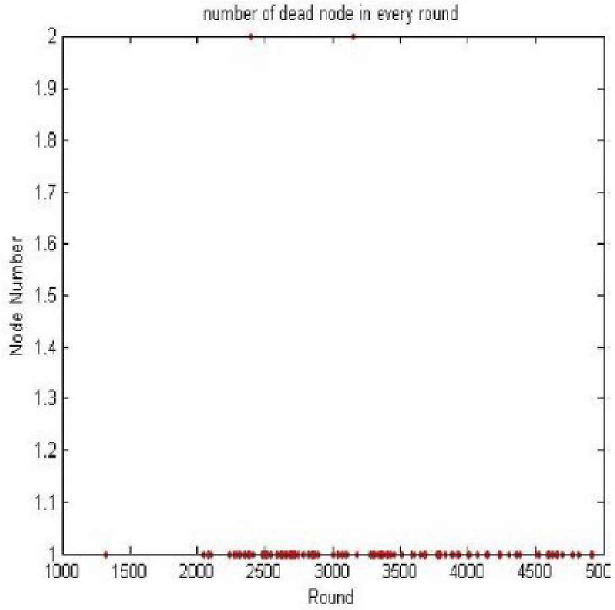

Fig. 13.Number of Dead Nodes in Each Round for Original TDTCGE

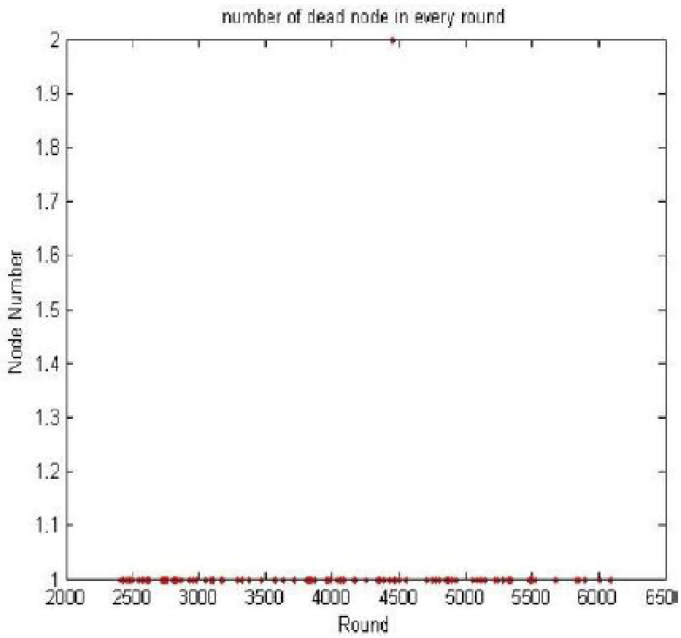

Fig. 14. Number of Dead Nodes in Each Round for the GMD Proposed Protocol

The FND values in TDTCGE with time parameters, original TDTCGE, and the proposed MD protocol are 1400, 1400,and 2300, respectively (see Figs. 13, 14, and 15). The proposed MD protocol enhances the FND by 64% compared with the original TDTCGE and TDTCGE with time parameters. The LND in the proposed protocol is 6100, and that in TDTCGE with time parameters and the original TDTCGE is 3600 and 4880, respectively. The improvement percentage of the proposed protocol is 23% and 66% over TDTCGE with time parameters and the original TDTCGE, respectively. Many nodes die immediately after the death of the first node at 1400 rounds in TDTCGE with time parameters (see Fig. 13). The second node dies at 2100 rounds in the original TDTCGE because the nodes are extremely near the CH. Therefore, the nodes consume less energy than those in TDTCGE with time parameters.

TDTCGE with time parameters consume more energy because the nodes are always awake for packet transmission. Consequently, the nodes die quickly after 1400 rounds in this protocol.

5.1 Comparison between GMD simulation and GMD Mathematical Model

The Simulation using some parameters that do many comparisons with previous protocols to prove that The GMD Mathematical model is improving the overall lifetime for these nodes in the Environment more than previous protocols as MD original and TDTCGE also GMD simulation .

Table4 .change some parameters in the simulation

Position of BS	Number of grids	Number of nodes
(0,0)	4	50
(50,50)	9	100
(100,100)	16	150

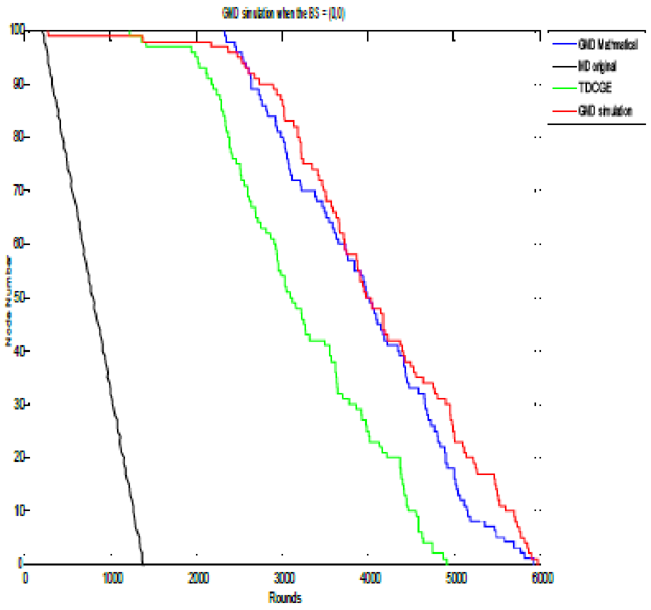

Fig. 15. when position of BS=(0,0).

When the position of BS at (0,0) :

• The first node die (FND) after 200 round and the last node die (LND) after 6000 round for GMD simulation.

• The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.

• The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.

- The first node die(FND) after 200 and the last node die (LND) after 1400 round

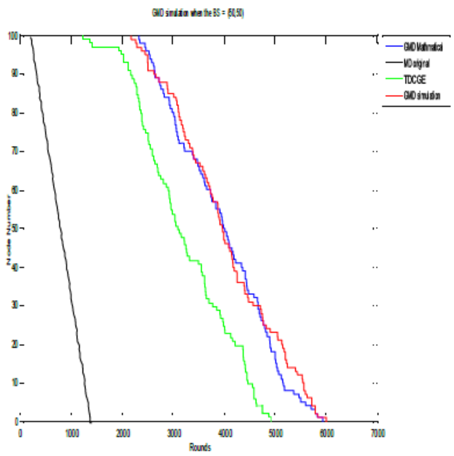

Fig. 16. when position of BS=(50,50).

When the position of BS at (0,0) :

- The first node die (FND) after 200 round and the last node die (LND) after 6000 round for GMD simulation.
- The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.
- The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.
- The first node die(FND) after 200 and the last node die (LND) after 1400 round

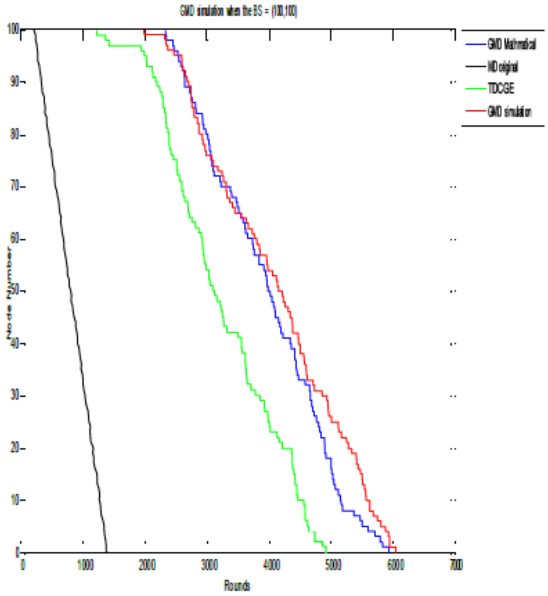

Fig. 17. when position of BS=(100,100).

When the position of BS at (100,100) :

- The first node die (FND) after 2000 round and the last node die (LND) after 6000 round for GMD simulation.
- The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.
- The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.
- The first node die(FND) after 200 and the last node die (LND) after 1400 round

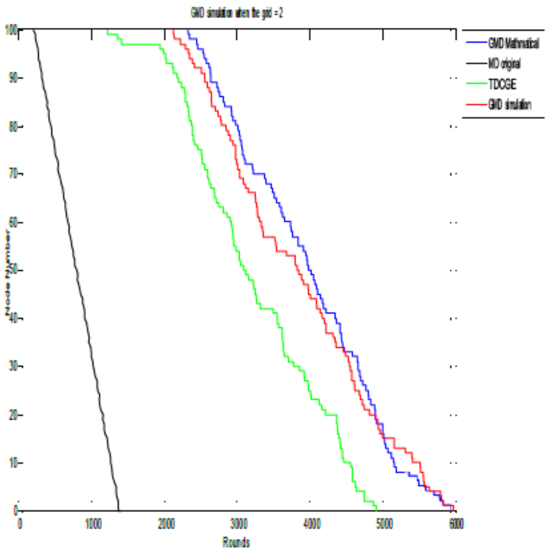

Fig.18. when grid=4

When the grid =4 :

• The first node die (FND) after 2100 round and the last node die (LND) after 6000 round for GMD simulation.

• The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.

• The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.

• The first node die(FND) after 200 and the last node die (LND) after 1400 round

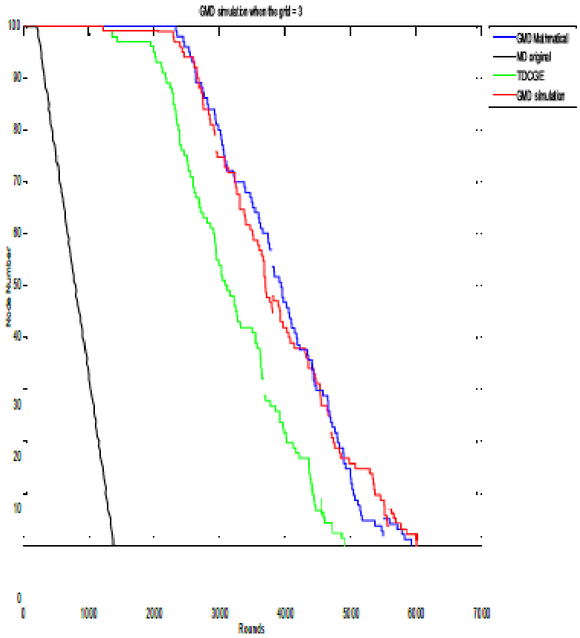

Fig.19. When grid =9

When the grid =9: 30

• The first node die (FND) 25

after 1200 round and the last
20
node die(LND) after 6000 round for GMD simulation.

• The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.

• The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.

• The first node die(FND) after 200 and the last node die (LND) after 1400 round

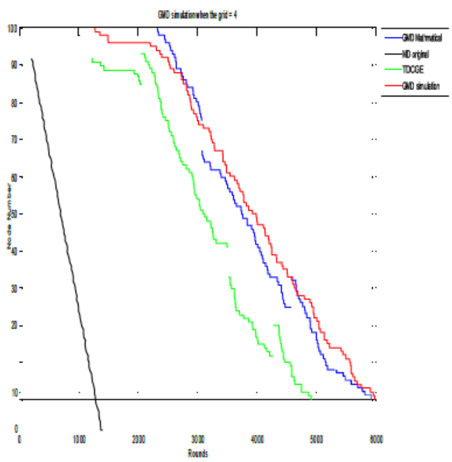

Fig. 20 . when grid =16

When the grid=16 :

• The first node die (FND) after1300 round and the last node die (LND) after 6000 round for GMD simulation.

• The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.

• The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.

• The first node die(FND) after 200 and the last node die (LND) after 1400 round.

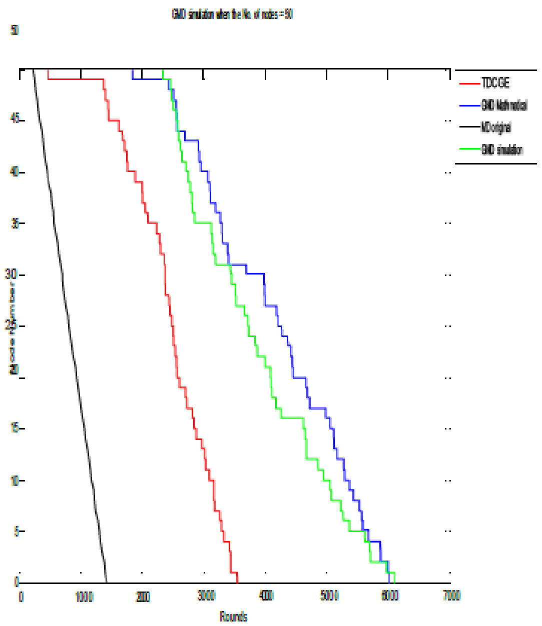

Fig. 21. When number of node =50

When the number of nodes =50 :

• The first node die (FND) after 3000 round and the last node die (LND) after 6000 round for GMD simulation.

• The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.

• The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.

• The first node die(FND) after 200 and the last node die (LND) after 1400 round

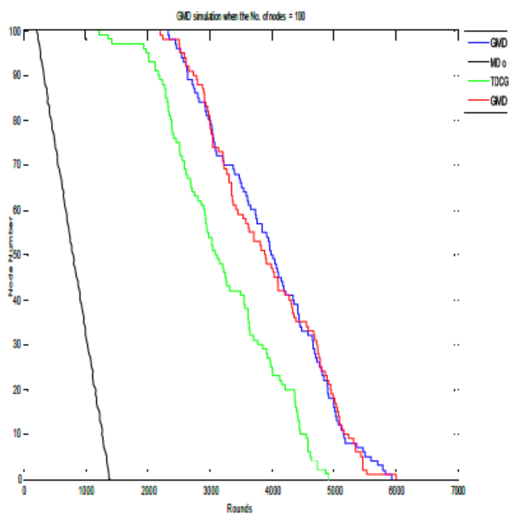

Fig. 22. When the position of BS at (75,125)

When the number of nodes =100 :

- The first node die (FND) after 2100 round and the last node die (LND) after 6000 round for GMD simulation.
- The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.
- The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.
- The first node die(FND) after 200 and the last node die (LND) after 1400 round

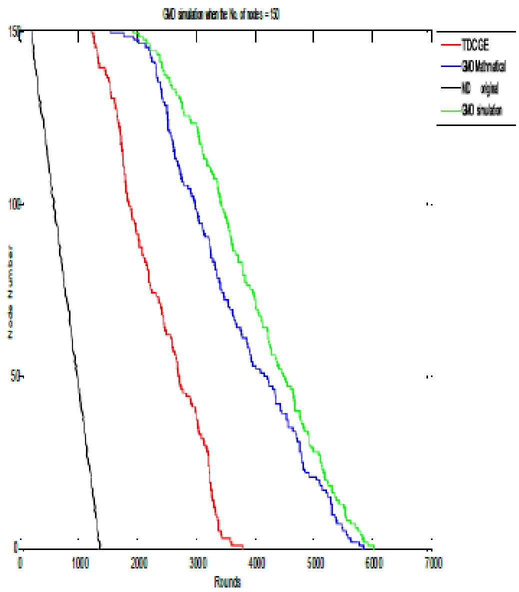

Fig. 23. When number of node =150

When the grid =150:

The first node die (FND) after 2800 round and the last node die (LND) after 6000 round for GMD simulation.

- The first node die (FND) after 2300 round and the last node Die (LND) after 6000 round for GMD Mathematical.
- The first node die(FND)after 1400 and the last node die(LND) after 4880 round for TDTCGE Protocol.
- The first node die(FND) after 200 and the last node die (LND) after 1400 round

VI. CONCLUSION

From figures above , shows that if number of grids are decreasing from 16 to 4 grids ,The first node die (FND) will revive and extend the life time for the life time for the first node from 200 round to 2200 . The position of the BS will effect on the first node die(FND) and extend the lifetime for the first node from 200 round to 2200 round by increasing the position of BS from (0,0) to (75,125). The optimal case for the comparisons between GMD Simulation and GMD Mathematical model when the life time of GMD simulation is nearest to the GMD Mathematical model with simple advantage for GMD Mathematical model when the number of grids are 4 and the position of BS is (75,100) and number of nodes 100.

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