

Original Research Paper

# Comparative Study on Energy Efficient in Traveling Wave Pulse Coupled Oscillator for Wireless Sensor Networks

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**Abstract:** WSNs are unable to afford simultaneous transmission and reception of data and for most scenarios, the battery replacement is impossible upon the exhaustion of a node's battery energy. Thus, energy efficient protocols constitute vital design requirements for the WSN as a whole in order to increase the lifetime and ensure successful transmission of data from sensor node source to target, it becomes necessary to maintain sensor node's availability. Traveling Wave Pulse Coupled Oscillator (TWPCO) has proven to be robust, efficient and resistant to counteract deafness under various WSN including analytical models. However the extent to which energy efficient is consumed in sensor nodes, which deploys TWPCO as its self-organization has never been mentioned. To overcome this limitation, we performed a comparative study on energy efficient in TWPCO for WSNs. Using self-organizing scheme energy efficient WSNs by adopting a traveling wave biologically inspired network systems based on phase locking of Pulse Coupled Oscillator (PCO) model regards sensor nodes as observed in the flashing synchronization behaviors of fireflies and secretion of radio signals as firing. The simulation work was done using Java programming language. Energy efficiency in the random variant of both schemes (TWPCO and PCO) was also observed to be higher than the priority variant of the schemes.

**Keywords:** WSN, TWPCO, PCO, Energy Efficient

## Introduction

Over the last few years, Micro-Electrical Mechanical Systems (MEMS), especially Wireless Sensor Networks (WSNs) have attracted considerable attention from researchers. WSNs are small and inexpensive devices with sensing, processing and transmitting capabilities of environmental phenomena of interest. They have various application prospects, including military, industrial and agricultural monitoring systems (Al-Mekhlafi *et al.*, 2013). In addition, the limited processing capability and communication radius are two important features characterizing the WSN technology (Dutta *et al.*, 2012). Since these restrictions are crucial to the overall lifetime of the WSN, they need to be considered when designing a routing protocol (Saleh *et al.*, 2012). Because the failure of individual nodes directly represents the whole network with time, it is more likely for packet relaying and regular sensing to the base station to be exposed to serious jeopardization.

This is more possible, especially because more and more sensors will cease operations due to their exhausted energy (Senouci *et al.*, 2012). Each routing protocol algorithm transmits data from the sources to the destinations and it is expected to increase the network exposure, even if the propagation value decreases (Jacobsen *et al.*, 2011). Yet, one of the most serious issues faced by the WSN technology has been the issue of coverage-holes. Thus, the only remaining feasible deployment option or alternative in medium and large deployments in hostile regions is random dropping of Sensor Nodes (SNs) by unmanned vehicles or low flying helicopters. Even when there is a possibility of deterministic deployment, the issue of coverage-holes will be faced, especially because of the sensors running out of battery energy. Such an issue gets more evidently challenging, particularly for those nodes situated within close proximity to the base station. Such nodes usually represent the system bottleneck because of their high data-relaying task. In addition, sensor nodes are left to

operate independently after they are initially deployed, thus complicating the issue of coverage. As described by (Sharma *et al.*, 2012), WSN represents a group of thousands of tiny sensor nodes which are capable of performing wireless commandoes, which limited calculation and sensing. commandsness problem is associated with the RTS or Clear-To-Send (CTS) packet in the IEEE 802.11 MAC protocol (Committee, 1999) and occurs when a transmitter sends a control packet to initiate a transmission while the destination is tuned to another channel. After sending multiple requests, if the transmitter does not receive any response, it may conclude that the receiver is no longer reachable (Karapistoli *et al.*, 2009).

Therefore, in a network of sensor nodes, the wireless sensors collaboratively sense the environment, detect the phenomenon of interest and eventually forward the data to a dedicated base station in synchronization. This synchronization between the nodes is required for coordinating the cycles of power or efficiency of energy and for the stable functioning of sensors in real-time monitoring scenarios (Al-Mekhlafi *et al.*, 2014b). One of the techniques that may be employed to model the behavior of WSN is the Pulse-Coupled Oscillator (PCO) algorithm, where sensor nodes as observed in the flashing light emission synchronization behaviors of fireflies and secretion of radio signals are regarded as firing to attract mating partners (Robert and Wilfried, 2009). Wireless sensor nodes are associated with strict energy requirements and dynamic topology changes. Thus, the proposed PCO technique must cater for these dynamics in order to afford a successful implementation; thereby enhancing not only the packet drop rate but also the network lifetime (Keswani and Bhaskar, 2016). Nevertheless, WSNs are unable to afford simultaneous transmission and reception of data and for most scenarios, the battery replacement is impossible upon the exhaustion of a node's battery energy. Thus, energy efficient protocols constitute vital design requirements for the WSN as a whole. Another important requirement of WSNs is the self-organizing capability which enables sensor nodes to re-discover their new neighbors (due to battery exhaustion or abrupt malfunction of some nodes in the network) in the face of dynamic network topology changes. In general, energy efficiency is ensured in WSNs by explicit embedding energy-minimization protocols into the underlying sensing model of the sensors (such as reducing the per packet energy consumption) or avoiding the high energy usage of any single node within the network (Taniguchi *et al.*, 2013).

In this study, we performed a comparative study on energy efficient in TWPCO for WSNs. Using self-organizing scheme energy efficient WSNs by adopting a traveling wave biologically inspired network systems based on phase locking of Pulse Coupled Oscillator

(PCO) model regards sensor nodes as observed in the flashing synchronization behaviors of fireflies and secretion of radio signals as firing (Taniguchi *et al.*, 2013). The simulation work was done using Java programming language. Energy efficiency in the random variant of both schemes (TWPCO and PCO) was also observed to be higher than the priority variant of the schemes.

## Related Works

### *TWPCO and PCO*

This section reviews the background of the TWPCO and PCO models for WSNs. PCO is used to explain the synchronous behaviors of the biologically inspired network systems that are divided into three part pacemaker cells as observed in the flashing synchronization behaviors of fireflies and neurons (Lyu 2016; Taniguchi *et al.*, 2007a). However, the review of this paper concentrates on the TWPCO and PCO model which are based on the synchronous flashing of the synchronization behaviors of fireflies. This model utilizes the firefly synchronization behavior of attracting mating partners (Robert and Wilfried, 2009; Wieser *et al.*, 2013). Yet, the PCO model is not suitable for sensor networks given the fact that the WSN nodes are usually unable to receive data packets while transmitting them due to the deafness (Robert and Wilfried, 2009; Taniguchi *et al.*, 2013). This problem is generally addressed by adopting the PCO model based on traveling wave as observed in flashing firefly as firing.

Another important research consideration in WSNs is energy efficiency. In WSNs, energy efficiency is ensured by explicit embedding energy minimization protocols into the underlying sensing model of the sensors (such as reducing the per packet energy consumption) or avoiding the high energy usage of any single node within the network (Al-Mekhlafi *et al.*, 2014a; Kawale and Makandar, 2015; Phung *et al.*, 2013; Wang *et al.*, 2012). Therefore, the energy efficiency for transmission scheduling in time synchronization on WSNs is classified into a sender and a receiver (Al-Mekhlafi *et al.*, 2014a). The transmission scheduling problems at the sender, which is the focus of the current study, are collision, deafness and hidden terminal. For the problems related to the transmission scheduling at the receiver, they are idle listening and overhearing.

Mimicking the behavior of fireflies can result in developing WSNs. Fireflies resemble sensor nodes in terms of their decentralized behaviors that are characterized by restricted individual processing capabilities (Al-Mekhlafi *et al.*, 2014a). In addition, communication of fireflies is described to be largely local. Regarding firefly models which are biologically inspired, they are classified into mathematical models and biological models (Meisel *et al.*, 2010; Tyrrell *et al.*,

2007). As reported in previous research, the applications of these models have been documented in a variety of WSN work for inter-node communication. Phung *et al.* (2013), the researchers proposed a multichannel protocol for high-bandwidth WSNs by combining TDMA and frequency division multiple accesses. This protocol was intended to overcome the problems of deafness and packet collision scheduling of transmissions. In this regard, the same researchers used to reinforce learning for collaborating scheduling and routing in each node in conjunction with the service quality (i.e., Packet delivery ratio, end to end latency and energy waste factor). This study could achieve the anticipated conditions easily and frequently with a minimal latency and packet loss. As reported by those researchers, the developed protocol was capable of exhibiting improved operations related to end-to-end delivery rate and end to end latency and enhancing the energy efficiency compared to other protocols.

Taniguchi *et al.* (2013), the researchers first developed a self-organizing mechanism which relied on phase-locking in PCO aimed at propagating the sensor node of data from the rim of the network to the sink to hop count for the purpose of avoiding deafness. A simple random-based scheme and a desynchronization-based scheme were proposed on the center of the anti phase in PCO model. It is to overcome the problem of collision among sensors while maintaining the same hop count that is attained by means of the energy efficient ratio and data-gathering ratio. The desynchronization-based mechanism developed by those researchers suits the applications of WSN which need a high level of data collection as well as efficient and clearness of a scheme instead of only data-gathering ratio.

The above investigations of previous research enrich our understanding of distinguishing among communication phases, acquisition and network synchronization where the data is transmitted and received. Yet, the above proposed schemes in previous research do not suit the applications of WSNs since WSNs subject to the changes of topology.

### *Energy Efficient*

The most significant issue is the limited energy resources for all protocols of sensor node networks. Sensor node networks use small, low-cost, high performance batteries, particularly in large-scale networks and when sensor nodes are in difficult-to-serve locations. Thus, synchronous designs should consider the limited energy resources of sensor nodes (Sivrikaya and Yener, 2004). Sensor nodes in WSNs have various limitations concerning the power source, un-reachability, short transmission range and storage due to hazards environment (Keswani and Bhaskar, 2016). These limitations roughly affect the performance of the wireless networks when applied ineffective energy efficient method. As a result, enhancements to the

energy efficient methods become necessary to maximize network lifespan.

Hence, various studies address this issue and attempt to enhance the energy efferent by introducing new algorithms. There is a rich and a heterogeneous spectrum of solutions to maximize the network lifespan (Annabel and Murugan, 2015; Kawale and Makandar, 2015; Nokhanji *et al.*, 2015; Watwe and Hansdah, 2015).

Figure 1 shows a well-known deafness problem. Node A, which is a neighbor of node N, is unaware that N is in direct communication with another neighbor and attempts to communicate with N by sending a packet. Node N, which is a beam formed in a different direction, fails to hear the packet. Assuming congestion as the cause of failure, a backoff occurs before attempting retransmission. If data packets are large, then N remains engaged in communication to S for a long time, during which A may attempt multiple retransmissions, with each retransmission preceded by increasing backoff duration. When N finally completes its packet delivery and is ready to transmit a new one, A is highly likely to be counting down a larger backoff counter. Deafness occurs when node A continues to send RTS messages to node N and node N is deaf to these messages. Node N does not reply to any CTS message sent by node A, which then goes into backoff mode (Choudhury and Vaidya, 2004). Therefore, the deafness leads to long delay, wasting energy, excessive packet drop and channel access unfairness.

Robert and Wilfried (2009) suggested a self-organizing principle based on biological fireflies and used the PCO model for synchronous emission of light flashes with the aim of attracting mating partners as well as distributing the timing of light flashes in a particular time window. This can avoid deafness without creating any effect on the quality of synchronization. Their study didn't demand any dedicated synchronization node and therefore, no single point of failure occurred. In addition, it was found that the additional rate calibration scheme permits for a longer interval of resynchronization and allows using cheap oscillators with high drift rates as features for low cost sensor nodes. Furthermore, a synchronization precision lower than 1 ms is possible to achieve in this scheme.

The authors in (Taniguchi *et al.*, 2007a) developed a self-organizing communication scheme and a fully-distributed for WSNs which focused on investigating initial conditions that result into creating a desirable shape of traveling wave regains of the initial phase of oscillators in a PCO scheme. Their suggested scheme was proved to be capable of collecting information according to the requirements of applications in a dynamic WSN and of delivering sensor node information from/to appoint sensor nodes in an energy efficient manner than (Taniguchi *et al.*, 2007a) though it consumes time for generating a traveling wave.

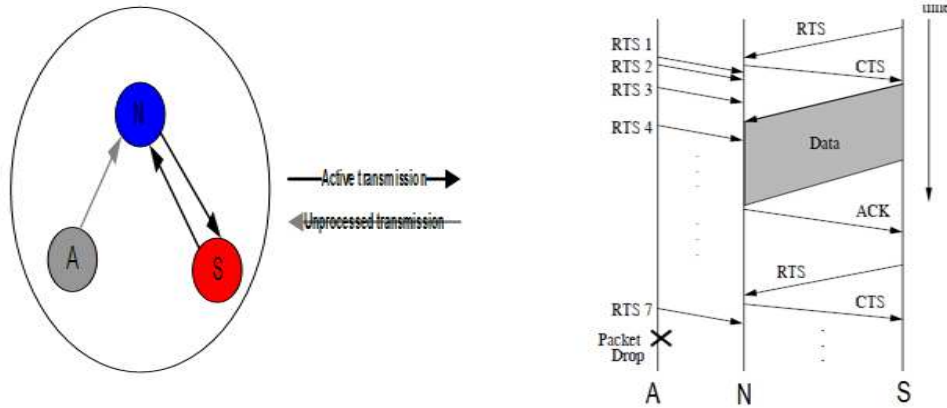


Fig. 1. Sensor node that explains the deafness problem. Source: (Choudhury and Vaidya, 2004)

The researchers in (Pagliari and Scaglione, 2011) proposed a network synchronization method which was developed based on the PCO model. This proposed method indicates that the PCO can be a reasonable option to classic MAC policies and it plays a role in motivating additional research into investigating cooperative communications.

Yamamoto *et al.* (2011), the authors presented a stepwise synchronization-based inter-networking method based on the PCO model to achieve stepwise synchronization separately and accomplish smooth and moderate inter-networking between WSNs with diverse operational frequencies. Their studies did not evaluate the suggestion in such scenarios where there are more than three networks to cooperate and the degree of the number of border nodes overlaps and changes dynamically.

## Materials and Methods

The PCO technique (Goel and Ermentrout, 2002; Mirollo and Strogatz, 1990; Nishimura, 2015; Yamamoto *et al.*, 2011) involves the synchronization behavior of a number of oscillators, in which an oscillator fires only when its timer reaches 1. The traditional PCO technique describes a number of synchronous firefly behaviors, namely (Nishimura, 2015), in-phase, anti-phase and phase-locking, according to PCO synchronization. The in-phase-based on scenario completely synchronizes the oscillator; the anti-phase-based on scenario ensures the synchronization of the oscillator at equal intervals and the phase locking based on PCO synchronization, such as traveling wave involves the synchronization of the oscillator with a constant offset. To our knowledge, this is the first study to apply both biologically inspired network systems based on phase locking of PCO model and non-biologically inspired network systems based on anti-phase of PCO model in term of energy-consumption and data gathering in WSNs.

Given a set of  $N$  oscillators  $\phi_i$  (where  $1 \leq i \leq N$ ) and each oscillator  $\phi_i$  is associated with a phase  $\theta_i$  such that  $\theta_i \in [0, T]$ . With the passing of time, the  $\theta_i$  is bound to shift towards  $T$  (which is the maximum). At  $T$ , the oscillator  $\phi_i$  fires before  $\theta_i$  returns back to zero. Similarly, the oscillator  $\phi_j$ , which is paired with the firing oscillator  $\phi_i$  is stimulated. This moves the corresponding phase  $\theta_j$  by an infinitesimal amount  $\Delta(\theta_j)$ , where:  $\theta_j = \Delta(\theta_j) + \theta_j$ . By a total by an infinitesimal amount ( $\theta_j$ ) as pursues:

$$\theta_j = \Delta(\theta_j) + \theta_j \quad (1)$$

where,  $\Delta(\theta_j)$  stands for the PRC, which is widely used by experimentalists to quantify the behavior of the system without knowing the underlying mechanisms responsible for the behavior (Achuthan and Canavier, 2009; Ermentrout *et al.*, 2012; Goel and Ermentrout, 2002; Sato *et al.*, 2011; Taniguchi *et al.*, 2007a; Wang and Doyle, 2012). The PCO firing is presented by adopting the traveling wave equation based on phase-locking of the PCO model.

The proof of Equation 1, in particular  $\Delta(\theta_j)$ , is based on the Quadratic Integrate and Fire (QIF) model (Goel and Ermentrout, 2002) and PRC function satisfies (Taniguchi *et al.*, 2013), which are presented based on the following models:

$$\Delta_{QIF}(\varnothing) = PRC_a(1 - \cos(2\pi\varnothing)) \quad (2)$$

$$\begin{cases} 0 < \Delta(\varnothing) \leq 1 - T - \varnothing & (0 \leq \varnothing < 1 - T) \\ \Delta(\varnothing) = 0 & (\varnothing = 1 - T) \\ 1 - T - \varnothing \leq \Delta(\varnothing) < 0 & (1 - T < \varnothing < 1) \end{cases} \quad (3)$$

From Equations (2 and 3), we can generate the following new equation:

$$\Delta_s(\varnothing) = PRC_a \times \sin \frac{\pi}{1-T} \times \varnothing + PRF_b(1 - T - \varnothing) \quad (4)$$

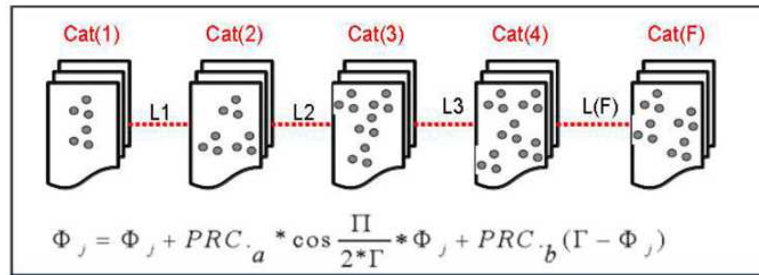


Fig. 2. Classification of sensor nodes into several categories or levels

As a result, the TWPCO equation proved from Equation 4 and applied in Equation 1 catalyzes the sensor node and modifies its phase as follows:

$$\varnothing_j = \varnothing_j + PRC_a \times \cos \frac{\pi}{2 \times T} \times \varnothing_j + PRC_b (T - \varnothing_j) \quad (5)$$

Thus, the traveling wave phenomena can be systematized in data gathering and diffusion based on the biologically inspired network systems of phase locking in the PCO model (Lanford III and Mintchev, 2015; Lv and Wang, 2010; Taniguchi *et al.*, 2007b). The PCO scheme does not only exhibits the universal synchronization wherever all oscillators fire synchronously, but it also displays the TWPCO, where oscillators behave synchronously with a different fixed phase.

In the TWPCO model, each individual sensor broadcasts the gathered data within the phase of its own timer. In this manner, the network adjusts the phase of its own timer accordingly whenever a sensor detects transmissions from another node. By collaborating with their neighbors, sensor nodes eventually enter the phase-locking state in which the sensor data are emitted. In this scenario, the timing of a message being emitted is regarded as a traveling wave phenomenon, whose center occurs at the sensor node and seeks to either gather or disperse information from or to all sensor nodes.

Here, each sensor node  $n_i$  (where  $1 \leq i \leq N$ ) has a timer of phase  $\varnothing_i$ , level  $l_i$  and offset  $t$ . In the algorithm, the level field is an indication of each sensor's hop count from the BS. Each sensor's level field is assigned a large value at initialization. The offset  $t$  is the data transmission interval between a sensor node of level  $l$  and that of  $l - 1$ . Thus, when the phase  $\varnothing_i$  reaches  $T$ , the sensor node  $n_i$  sends a broadcast message that contains the control information and sensor data and then the phase returns to zero. Upon the reception of a message by node  $n_j$  from  $n_i$ , such that level  $l_i < l_j$ , the node  $l_j$  adjusts its level as  $l_j = l_i + 1$ .

According to our TWPCO scheme, the node catalyzes and modifies its phase where  $PRC_a$  and

$PRC_b$  are the factors that decide the rate of assemblage as shown in Equation 5. By using Equation 5 in the PRC function, regardless of the initial phase of nodes, the traveling wave phenomena based on phase-locking in the PCO model are performed during common communication between sensor nodes. Figure 2 shows the classification of sensor nodes into several categories or levels.

### Simulation

#### Assumptions

In this study, we carried out observations and assessment of the simulation, experimental results so that we could evaluate the performance under a variety of WSN environments.

Based on the experimental results, we scheme plays an important role in enhancing the energy efficiency and data gathering and extending the sensors' steady states. Such improvement achieved by the TWPCO scheme is attributed to the process of adjusting the quality evaluation of the functions, which as a result, contributes to enhancing the accuracy of the firefly based on the PCO algorithms. In order to validate the TWPCO scheme, the results of the experiments were compared to the PCO (Taniguchi *et al.*, 2012). The next section will explain the experimental setup and assess the accuracy and results of the TWPCO scheme.

#### System Configuration

The suggested TWPCO mechanism was simulated by deploying different sensor nodes. The simulation environment involved a fixed  $100 \times 100 \text{ m}^2$  square field, with the sensor nodes randomly deployed. The BS was located at the  $50 \times 50 \text{ m}^2$  mark. The transmission radius of the nodes was 50 m, which was assumed to be perfectly omnidirectional. Specifically, the MICAz protocol is used in the study. Thus, whenever a node is sent to transmit messages from two different nodes simultaneously. Here, the data gathering ratio cycle,  $T$ , was set to 1 s, while the highest substitute,  $\tau^{\max}$ , was set to 0.1 s. From Equation 5,  $a$  and  $b$  were set to 0.01 and 0.5, respectively. The initial phase readings were



randomly set. The sizes of the message header and that of the individual sensor data were set to 2B, whereas that of the message transmission control information was set to 1B. The results of TWPCO scheme are then compared with PCO (Taniguchi *et al.*, 2012). In addition, to be more objective, we have re-implemented the PCO to work in the Java programming language in order to run both methods under the same simulator with similar software and hardware platforms. We then tested and validated the TWPCO method under the same scenarios and simulation setting used by PCO, in order to prove the effectiveness of TWPCO. A summary of the simulation parameters is displayed in Table 1.

## Results

This section discusses the main experimental results of the current study by which we validated the efficiency of our proposed TWPCO scheme in comparison to the PCO. These results were obtained by using the Java programming language. The results discussed here focus on two main aspects: The impact of the number of sensor nodes and the impact of packet data size on the assessed accuracy of the proposed scheme.

## Discussion

### *The Impact of the Number of Sensor Nodes between TWPCO and PCO*

From scenario I (Table 1 and Fig. 3), the data gathering ratio of the TWPCO scheme was compared to that of the PCO. Figure 3 demonstrates that in both mechanisms, there is a decline of the data gathering with an increasing number of sensor nodes. In scenario I, the data gathering ratio of the TWPCO scheme declined as

the number of the sensor nodes exceeded 40. This declining data gathering ratio could be due to the simulation results. Although the data gathering performance seemed to decrease, the TWPCO scheme still outperformed the PCO because the techniques used in our proposed scheme are more useful than those of the PCO. Specifically, the evaluation of the TWPCO scheme in comparison with the PCO revealed that the TWPCO method is up to 9% superior to the PCO in terms of data gathering. In addition, the packet data size of the TWPCO scheme is larger than that of the PCOs. This is because the packet data broadcast timing information was included in the TWPCO model. This improvement of the TWPCO mechanism is attributed to the fact that the TWPCO scheme uses the new mathematical model for calculating the hidden node problem.

Figure 4 shows that the performance of the TWPCO scheme was superior to the PCO in relation to the energy efficiency. This is due to the higher number of received packets in the TWPCO scheme that made its performance more efficient. Specifically, the TWPCO scheme exhibits a 25% higher energy savings performance compared to the PCO. As a result, the energy efficiency ratio of the TWPCO scheme reduces significantly compared to the PCO, thus exhibiting superior results.

### *The Impact of the Packet Data Size between TWPCO and PCO*

For scenario II (Table 1), Fig. 5 and 6 illustrate the data gathering and energy efficiency per sensor node datum size for both schemes. Concerning this, the data gathering ratio of the TWPCO scheme was higher than that of PCO (Fig. 5). This is one of the contributions of our proposed scheme reported in this study. This improvement is because of the categories of the levels of the nodes.

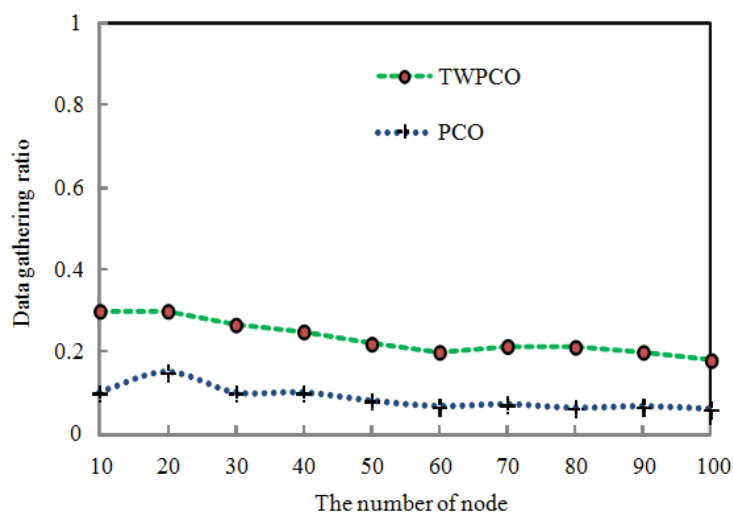


Fig. 3. Data gathering ratio based on the number of nodes

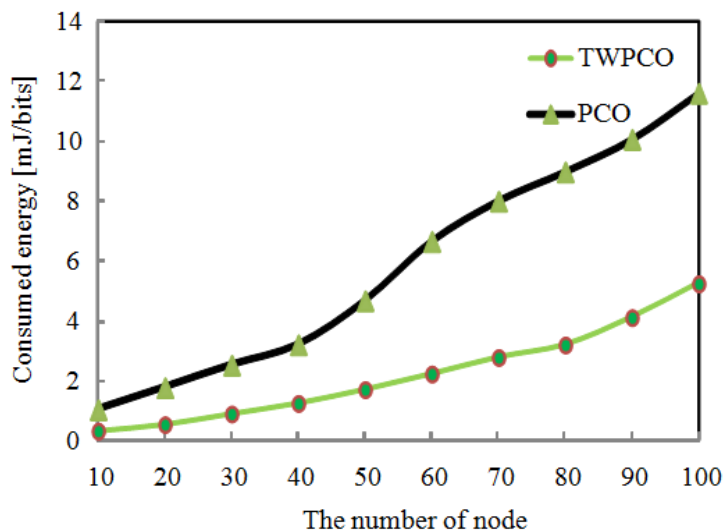


Fig. 4. Energy efficiency ratio based on the number of nodes

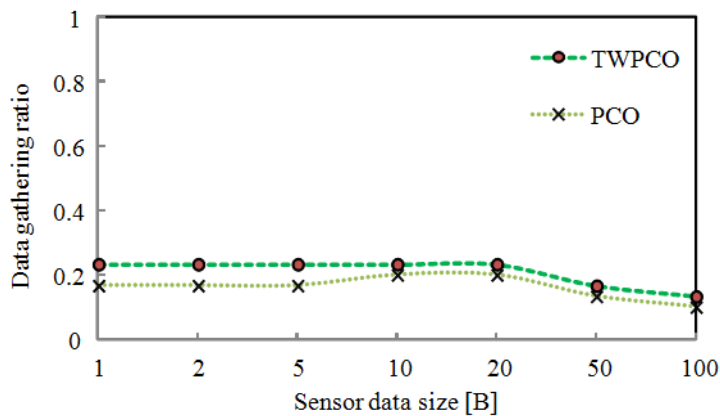


Fig. 5. Data gathering ratio based on a data packet size

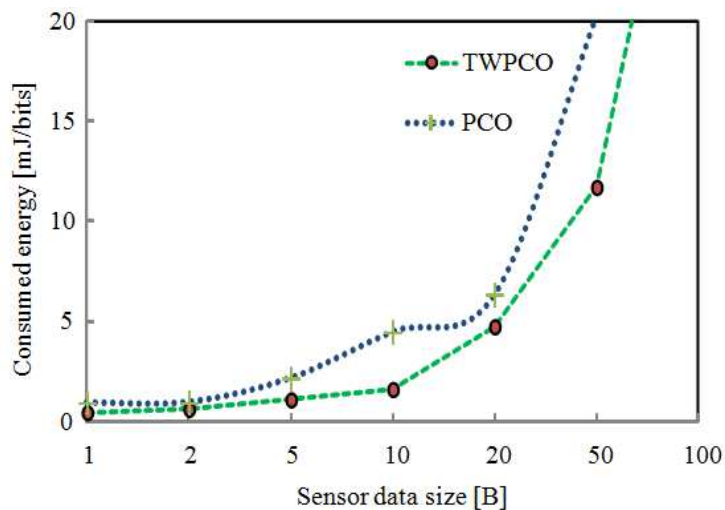


Fig. 6. Energy efficiency ratio based on a data packet size

Table 1. Parameters setup

Parameters	Values	
	Scenario I	Scenario II
Channel Frequency	2.4GHz	2.4GHz
Number of Nodes	10,20,30,40,50,60,70,80,90,100	30
MIN_TIME_STEP	0.00001	0.00001
Packet Data Size	16 bits	8,16,40,80,160,400,800 bites
Energy Model	MICAz	MICAz
Data Rate	250kbps	250kbps
Transmit Power	52.2 $\mu$ w	52.2 $\mu$ w
Receive Power	59.1 $\mu$ w	59.1 $\mu$ w
Idle Power	60 $\mu$ w	60 $\mu$ w
Sleep Power	3 $\mu$ w	3 $\mu$ w
INITIAL_ENERGY	100 Joules	100 Joules

The TWPCO scheme achieved 9% improvement in the data gathering ratio compared to the PCO. On the other hand, the energy efficiency ratio of the TWPCO scheme declined considerably compared to the PCO (Fig. 6). The decreasing ratio of energy efficiency of the PCO is an indicator of the weaknesses of this scheme.

To sum up, regardless of the sensor node data size, the TWPCO scheme exhibits up to 13% superior performance in comparison to the PCO in terms of the energy consumption ratio and data gathering ratio Fig. 3-6. Therefore, the TWPCO model for mimicking the flashing synchronization behavior of fireflies and secretion of radio signals as firing suits or fits the WSN applications with advanced data gathering ratio and energy efficiency ratio to counteract the issue of deafness. Also the figures show consumed energy due to packet collision.

Considering the shortcomings of energy model (for energy efficient scheme) in existence (Taniguchi *et al.*, 2013) our experiment plugged in the TWPCO model into a stateless WSN (Taniguchi *et al.*, 2007a; 2007b; 2013). It still captures the energy behavior and differences in the two novel schemes. This method of comparison can be considered suitable for determining energy efficient due to a packet collision between the two schemes.

## Conclusion

The study is limited to TWPCO and PCO and only considers the two states of data gathering and energy efficient because of WSN communication, the highest energies are consumed by the Transmit power and Receive power processes of a communication in a node. The priority alternative schemes whose operation has been distinguished as being deleted when choosing a next hop-node to, is quite related to the likes of a direct communication which is also extended to arrive at a sink. These priority alternative schemes (TWPCO and PCO) consumed less energy compared to the random alternative schemes whose operation has been described as erratic when choosing a next hop node. However, future research should confirm and improve the performance of these

mechanisms by using desynchronazition in the experimental evaluation as well as the actual sensing environment to avoid a packet collision.

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## Author's Contributions

**Zeyad Ghaleb Al-Mekhlafi:** Participated in all experiments, designed the research plan, organized the study, methodology and contributed to the writing of the manuscript.

**Zurina Mohd Hanapi:** Coordinated the mouse work, designed the research plan, organized the study, methodology and evaluation.

**Mohamed Othman:** Coordinated the mouse work and evolution the whole paper.

**Zuriati Ahmad Zukarnain:** Coordinated the mouse work and evolution the whole paper.

## Ethics

This article is original and contains unpublished materials. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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