Development of the Model for Wireless Sensor Network based on Swarm Intelligence and Internet of Things

Wafer Hazinji[1] and Aaron Zimba[2]

[1]Department of Computer Science, Mulungushi University, Kabwe, Zambia.
[2]Department of Computer Science, ZCAS University, Lusaka, Zambia
Corresponding Author: hazinjiwafer@gmail.com

***Abstract*-This article explains a model wireless sensor network based on Swarm intelligence and Internet of Things to enhance video security surveillance. The model was developed using OMNeT++ software. OMNeT++ is an application software that is used to create both wired and wireless networks. It has a collection of building blocks that can be configured in different ways to create a network. The networks created are all simulated to assess the effectiveness of the networks before they are physically implemented. The Data values from the simulated model such as count, mean and the standard deviation were used in calculations to prove the accuracy or validity of the simulation. The range of values obtained from the calculations is called confidence interval values and they point to the level of accuracy to include true parameter value of 95%. The Confidence Interval values obtained in the developed model were between -1.96 and 1.96 which indicated that the sample values from the project simulation represented 95% of the infinity population. The application here is that Confidence Interval values allow us to take a broad view of the validity of the project. The article seeks to achieve the following objectives: To identify application of Swarm Intelligence Technologies in wireless sensor networks, to develop a model wireless sensor network using OMNeT++ software and finally to attain the 95% confidence interval from the collected data values of the simulated model.**

Keywords: Swarm Intelligence, Wireless Sensor Networks, Confidence Interval

I. INTRODUCTION

A wireless sensor network (WSN) comprises a number of sensor gadgets or nodes that are distributed either indoor or outdoor environments. These nodes are able to communicate to each other and their location or position in the network structure depends on the preferred topology of the network [16].
The software surveillance systems make use of video cameras to monitor the environment in a given area. There are two types: ‘‘basic systems” and ‘‘systems with some degree of intelligence” [13].

Studies review that there has been a lot of effort to enhance the performance of wireless sensor networks by employing new techniques derived from the behavior of swarms such as bees, birds and ants and are called swarm intelligence techniques. These systems that have been inspired by behavior of swarms have proved to solve network problems found in large wireless sensor networks such as routing, high energy consumption by sensor nodes, heterogeneity and many other network problems. [12].

II. LITERATURE REVIEW

The literature below reviews Swarm intelligence in three main areas namely; Swarm intelligence technologies, application of Swarm intelligence technologies in wireless sensor networks and reviewed systems.

A. *Swarm intelligence technologies*

Swarm intelligence technologies are a computational intelligence techniques that employs the study of behaviours of certain animals or systems that are made of self-organized components and are able to coordinate. [10].

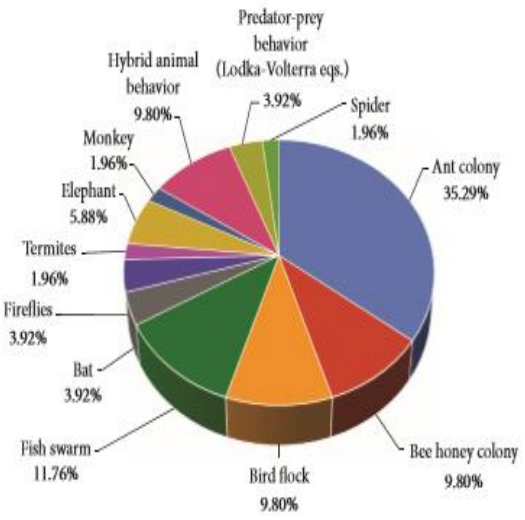

Figure 1. Bio inspired mechanism [12].

The agents maintain decentralized state by following simple rules. The agents make random movements and interactions and that results in a global intelligent behavior to achieve a common purpose [4]. The algorithms formed by swarms or agents enable them to adopt simple rules. The interaction of the individual agents results in the formation of the overall behavior exhibited by the agents [11].

B. *Application of swarm intelligence technologies in wireless sensor networks*

Many swarm optimization algorithms have been introduced since the early 60's, evolutionary Programming to most recent, Grey Wolf Optimization. All of these algorithms have demonstrated their potential to solve many optimization problems [1]. The integrating of ICTs in research and teaching in developing countries is still a challenge that needs to overcome. As a result of that investing in ICT infrastructure and introducing new approaches to providing access to the Internet through NRENs has been done by developing countries [6].

C. *Reviewed systems*

The summary of the reviewed systems are shown in the table below in comparison with the proposed system.

TABLE 1. COMPARISONS OF EXISTING SYSTEMS AND THE PROPOSED SYSTEM

Existing systems	Source	Low static power consumption and change of state of device	Generating traffic input and data encryption	Route traffic input	Through put
Contemporary secured target locality(CSTL)	[28]	X	✓	✓	✓
BIM and IoT	[29]	X	✓	✓	✓
Monitoring a manufacturing environment	[16]	X	✓	✓	✓
Smart monitor	[30]	X	✓	✓	✓
Marine monitoring	[33]	X	✓	✓	✓
On Campus mobile platform	[31]	X	✓	✓	✓
Border sense patrol	[32]	X	✓	✓	✓
Monitoring vehicles for pollution	[34]	X	✓	✓	✓
Proposed system		✓	✓	✓	✓

III. METHODOLOGY AND CONCEPTUAL FRAMEWORK

A. *Selected Methodology*

The Agile method was the selected methodology for this project.

The term agile comes from the English word agility, which means "moving quickly and easily". This is applied to project management to portray the sharp move away from the methodology like the waterfall traditional project management. The traditional waterfall method explains a situation where a good number of processes following one another have to be executed before the final process is done in order to complete the project. The agile methodology works on the earliest possible time to build the software and to ensure that the software is easily used by the customers [7]. The agile project management help address knowledge-related interdependencies by establishing feedback processes and team-based organizing structures. There are three practices that are applied to this end: the continuous integration, the continuous analysis, and joint decision making [8]. Agile project management method in creating software application expects the need for flexibility and gives a level of pragmatism to a completed product [7]. The application of agile method brings about improvement of development process which results in fewer bugs, timely delivery, more and effective communication, quality product, better risk analysis, less over costs etc [9].

B. *Conceptual framework*

To reduce cost in order to maximize profit, researchers have implored the drawing of inspiration from nature to find solutions to many problems in science, engineering, technology and industrial processes [20]. The sensor nodes in wireless sensor networks use energy and therefore, energy efficiency is necessary in order to extend the lifespan of the energy supplier since the performance of the network depends on the trade-off among energy consumption, latency and reliability [21]. The energy consumption and energy supply life span are the independent and dependent variables respectively. The diagram that follows explains how the research process was carried out.

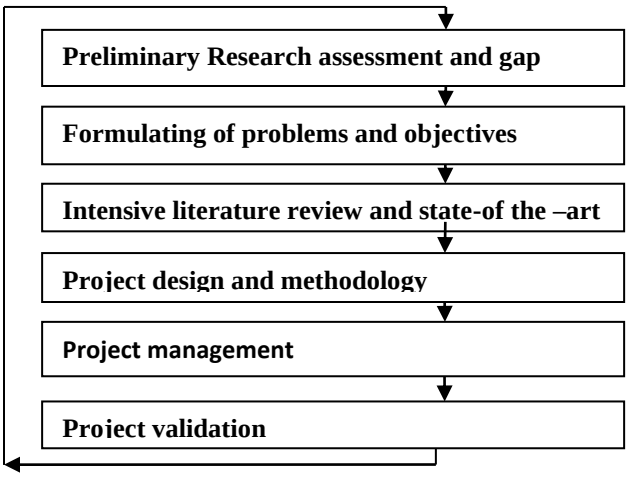

Figure 2. Research process

The strategy to mitigate the problem was to create a simulation that was suitable to mitigate the problems identified using software before it can be physically implemented.
The prototype was designed and in the prototype, details of the project in terms of sensor nodes positioning based of the files created for the simulation were to be outlined.
The implication of the project research is that, it will contribute towards designing the best wireless sensor network algorithms based on Swarm Intelligence and IoT techniques before the project is physically implemented.

IV. EXPERIMENT USING OMNET++ SOFTWARE

OMNeT++ is an open source application software that is used to create and simulate different types of networks. It is free to use for students in institutions to do their researches and it is also free to use by individuals for non-commercial use. OMNeT++ has module for models that are programmed in C++ programming language. OMNeT++ contains an integrated development environment that provides rich capabilities for analyzing models [18]. OMNeT++ has a generic architecture that can be used to analyze the performance and the functionality of wired and wireless communication networks. [15]. The figure below shows the sensor nodes; are able to generate inputs and send them to the Sever. The server in the middle acknowledges the receipt of inputs from sensor nodes. The OMNeT++ software generates the table of count, mean and the Standard deviation of the simulation. These values are further used to calculate the Confidence Interval.

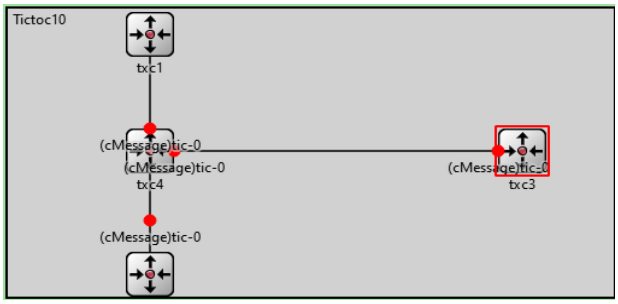

Figure 3. Simulating model of the experiment

V. RESULT PRESENTATION OF MAJOR FINDINGS AND DISCUSSIONS

TABLE 2. UNIT TEST PLAN

S/NO	TEST SCENARIO	ACTIONS	ACTUAL OUTCOME	PASS/ FAIL
1	Sensor node detecting object motion	Generating input of a detection and send to Server	Image of the object detected sent to the Server	✓
2	Server receives input from the sensor nodes	Server receives input from the sensor nodes	Server receives input from the sensor nodes and then it sends an acknowledgement to the sensor node	✓
3	The sensor nodes becomes active when they detect motion and when they receive acknowledgement from the Server	They rest if no detection of object, generate input when there is object detected.	Generate input when there is object detected.	✓

TABLE 3. THE COUNT, MEAN AND STANDARD DEVIATION VALUES OF THE OUTPUT VECTORS FROM THE EXPERIMENT

Experiment	Count	Mean	StdDev
PureAloha2	1	0	n.a.
PureAloha2	7	0.428571	0.534522484
PureAloha2	5	0.4	0.547722558
PureAloha2	3	0.333333	0.577350269
PureAloha2	3	0.333333	0.577350269
PureAloha2	3	0.333333	0.577350269
PureAloha2	3	0.333333	0.577350269
PureAloha2	3	0.333333	0.577350269
PureAloha2	3	0.333333	0.577350269
PureAloha2	20	0.7	0.732695097

The networks both wired and wireless continue to grow in industries, building networks on emulation application software before physically implementing it or before putting it on a production network is less costly. Therefore, the validation of network performance is usually conducted using emulation [15].

A. *System Testing*

Testing the Software application is done for the purpose of bringing hidden defects into identifiable ones. This phase of the software development life cycle enables developers to work out the defects that have been uncovered in a software product. Every software application product that has been created need to be tested to make sure that all hidden bugs have been eliminated before it is delivered to the users. This guarantees a customer of the quality of the product [5]. The objectives of a software testing are to complete a product that will give quality assurance to the customer. Software quality assurance activities play an important role in producing high quality software [19].

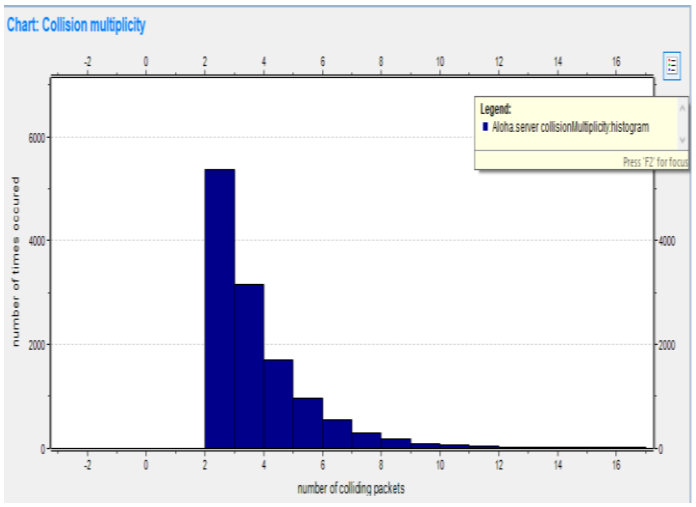

Figure 4. Server collision multiplicity histogram

The histogram above shows the collision multiplicity of number of packets and it confirms that the network is able to do more than 4000 processes at a time with a possibility of only two packet collision and hence the validity of the network.

B. *Validating the project*

Project validation is done to ensure that the software product created performs to expectations. The process assures the removal of uncertainties by using appropriate concepts in order to give clarity and overall suitability [9].

C. *Standard error of the mean (SEM)*

The Standard error of the mean is an intermediate step in the calculations to attain the 95% confidence interval (CI). It describes the distribution of the means in the hypothetical studies (2). This means that Standard error of the mean shows the accuracy with which sample mean $\bar{X}$ approximate the mean μ population. The accuracy increases as the sample size increases. Mathematically, Standard error of the mean is expressed as:

$$\sigma m = \frac{s}{\sqrt{n}}$$

Where:

σm = SEM; s = SD of sample; n = sample size [3].

TABLE 4. STANDARD ERROR OF THE MEAN CALCULATED FROM THE RESULTS OF THE EXPERIMENT.

SAMPLE	STANDARD	STANDARD

SIZE (COUNT)	DEVIATION (SD)	ERROR OF THE MEAN (SEM)
3	0.577350269	0.32
5	0.547722558	0.24
7	0.534522484	0.20
20	0.732695097	0.16

D. *Confidence Interval (CI)*

To save time and resources when studying entire population, data collected is summarized using descriptive statistics. These findings are generalized using inferential statistics. [3]. The Confidence Interval is a range of values that are calculated from the sample observations, that is likely to contain the true population value but with some level of uncertainty. The confidence interval provides an approximation of the unknown population parameter because the interval computed from a sample does not include the actual value of the parameter. This means that the approximation process is carried out more than once. The 95% of the calculated intervals would be expected to contain the true value. CIs can be one or two-sided. A two-sided CI brackets the population parameter from both below (lower bound) and above (upper bound). A 95% CI does not mean that 95% of the sample data lie within that interval. A CI is an interval approximate of reasonable values for the population parameter. When finding the 95% CI of the mean, the z standard value which is 1.96 is used [17]. Mathematically, CI is expressed as:

$$95\%CI = \bar{X} \pm Z\frac{s}{\sqrt{n}}$$

Where:

s = SD of sample; n = sample size; Z (standardized score) is the value of the standard normal distribution with the specific level of confidence. For a 95% CI, Z = 1.96 [2].

TABLE 5. CONFIDENCE INTERVAL

SAMPLE SIZE	LOWER LIMIT	UPPER LIMIT	RANGE
3	-0.2972	0.9572	1.2544
5	-0.0704	0.8704	0.9408
7	0.028	0.812	0.784
20	0.3864	1.0136	0.6274

In the confidence Interval table above shows that the values obtained for CI are between -1.96 and 1.96 which indicates that the project simulation attained the standard confidence interval of 95%.

VI. CONCLUSION

The article looked at the model wireless sensor network that was developed using OMNeT++ software. The results of the model showed sensor nodes sending information to the server. The data values of count, mean and standard deviation from the simulation were used to validate the model. The comparison of the model with other eight existing systems was done and it was observed that the existing systems consume same quantity of power when transmitting information to the server or not. The steps in framework were that, preliminary research assessment and gap identification was done by reviewing recently published journal articles to assess and identify gaps, followed by formulation of objectives. This was later followed by intensive literature review and project design and methodology and finally project management and validation. The sample size (count), standard deviation and the standard error of the mean values were used to find the Confidence Interval of the project. The range of values for the Confidence Interval was from 0.6274 to 1.2544. Since these values were in between -1.96 and 1.96, indicates that they represented 95% confidence interval of the project simulation. The Server collision Multiplicity Histogram showed that more than 4000 processes can take place at a time without having packet collision and hence the validity of the network. The future works are that Swarm Intelligence Technology and calculated value of Confidence Interval should be incorporated when designing and implementing wireless and wired sensor networks so as to improve aspects such as handling large scale networks to avoid resource constraints.

REFERENCE

[1] M. N. Ab Wahab, S. Nefti-Meziani, and A. Atyabi, “A Comprehensive Review of Swarm Optimization Algorithms,” *PLOS ONE*, vol. 10, no. 5, p. e0122827, May 2015, doi: 10.1371/journal.pone.0122827.

[2] C. Andrade, “Understanding the Difference Between Standard Deviation and Standard Error of the Mean, and Knowing When to Use Which,” *Indian J. Psychol. Med.*, vol. 42, no. 4, pp. 409–410, Jul. 2020, doi: 10.1177/0253717620933419.

[3] P. Barde and M. Barde, “What to use to express the variability of data: Standard deviation or standard error of mean?,” *Perspect. Clin. Res.*,

vol. 3, no. 3, p. 113, 2012, doi: 10.4103/2229-3485.100662.

[4] S. Brezovnik, J. Gotlih, J. Balič, K. Gotlih, and M. Brezočnik, "Optimization of an Automated Storage and Retrieval Systems by Swarm Intelligence," *Procedia Eng.*, vol. 100, pp. 1309–1318, 2015, doi: 10.1016/j.proeng.2015.01.498.

[5] D. Kumar and K. K. Mishra, "The Impacts of Test Automation on Software's Cost, Quality and Time to Market," *Procedia Comput. Sci.*, vol. 79, pp. 8–15, 2016, doi: 10.1016/j.procs.2016.03.003.

[6] D. Kunda, C. Chembe, and G. Mukupa, "Factors that influence Zambian higher education lecturer's attitude towards integrating ICTs in teaching and research," *J. Technol. Sci. Educ.*, vol. 8, no. 4, p. 360, Jul. 2018, doi: 10.3926/jotse.338.

[7] G. Y. Koi-Akrofi, J. K. Akrofi, and H. Akwetey Matey, "Understanding the Characteristics, Benefits and Challenges of Agile it Project Management: A Literature Based Perspective," *Int. J. Softw. Eng. Appl.*, vol. 10, no. 5, pp. 25–44, Sep. 2019, doi: 10.5121/ijsea.2019.10502.

[8] O. Krancher, "Agile Software Development Practices and Success in Outsourced Projects: The Moderating Role of Requirements Risk," in *Agile Processes in Software Engineering and Extreme Programming*, vol. 383, V. Stray, R. Hoda, M. Paasivaara, and P. Kruchten, Eds. Cham: Springer International Publishing, 2020, pp. 56–72. doi: 10.1007/978-3-030-49392-9_4.

[9] A. Rasnacis and S. Berzisa, "Method for Adaptation and Implementation of Agile Project Management Methodology," *Procedia Comput. Sci.*, vol. 104, pp. 43–50, 2017, doi: 10.1016/j.procs.2017.01.055.

[10] M. Saleem, G. A. Di Caro, and M. Farooq, "Swarm intelligence based routing protocol for wireless sensor networks: Survey and future directions," *Inf. Sci.*, vol. 181, no. 20, pp. 4597–4624, Oct. 2011, doi: 10.1016/j.ins.2010.07.005.

[11] M. Schranz, M. Umlauft, M. Sende, and W. Elmenreich, "Swarm Robotic Behaviors and Current Applications," *Front. Robot. AI*, vol. 7, p. 36, Apr. 2020, doi: 10.3389/frobt.2020.00036.

[12] S. Sendra, L. Parra, J. Lloret, and S. Khan, "Systems and Algorithms for Wireless Sensor Networks Based on Animal and Natural Behavior," *Int. J. Distrib. Sens. Netw.*, vol. 11, no. 3, p. 625972, Mar. 2015, doi: 10.1155/2015/625972.

[13]G. Sreenu and M. A. Saleem Durai, "Intelligent video surveillance: a review through deep learning techniques for crowd analysis," *J. Big Data*, vol. 6, no. 1, p. 48, Dec. 2019, doi: 10.1186/s40537-019-0212-5.

[14] I. Strumberger, M. Minovic, M. Tuba, and N. Bacanin, "Performance of Elephant Herding Optimization and Tree Growth Algorithm Adapted for Node Localization in Wireless Sensor Networks," *Sensors*, vol. 19, no. 11, p. 2515, Jun. 2019, doi: 10.3390/s19112515.

[15] A. Zarrad and I. Alsmadi, "Evaluating network test scenarios for network simulators systems," *Int. J. Distrib. Sens. Netw.*, vol. 13, no. 10, p. 155014771773821, Oct. 2017, doi: 10.1177/1550147717738216.

[16] M. Carlos-Mancilla, E. López-Mellado, and M. Siller, "Wireless Sensor Networks Formation: Approaches and Techniques," *J. Sens.*, vol. 2016, pp. 1–18, 2016, doi: 10.1155/2016/2081902.

[17] A. Hazra, "Using the confidence interval confidently," *J. Thorac. Dis.*, vol. 9, no. 10, pp. 4124–4129, Oct. 2017, doi: 10.21037/jtd.2017.09.14.

[18] M. Ushakova, Y. Ushakov, I. Bolodurina, A. Shukhman, L. Legashev, and D. Parfenov, "Creation of adequate simulation models to analyze performance parameters of a virtual fog computing infrastructure," *Procedia Comput. Sci.*, vol. 186, pp. 603–610, 2021, doi: 10.1016/j.procs.2021.04.182.

[19] K. Karnavel and R. Dillibabu, "Development and Application of New Quality Model for Software Projects," *Sci. World J.*, vol. 2014, pp. 1–11, 2014, doi: 10.1155/2014/491246.

[20] J. B. Odili, M. N. M. Kahar, and S. Anwar, "African Buffalo Optimization: A Swarm-Intelligence Technique," *Procedia Comput. Sci.*, vol. 76, pp. 443–448, 2015, doi: 10.1016/j.procs.2015.12.291.

[21] Z. Ye and H. Mohamadian, "Adaptive Clustering based Dynamic Routing of Wireless Sensor Networks via Generalized Ant Colony Optimization," *IERI Procedia*, vol. 10, pp. 2–10, 2014, doi: 10.1016/j.ieri.2014.09.063.