Panamerican Mathematical Journal
ISSN: 1064-9735
Vol 33 No. 3 (2023)

Development and Mathematical Formulation of Secured Memory Efficient Cloning Detection Protocol in WSNs using RSA Algorithm

Pranav P Chippalkatti[1], Swagat M Karve[2], Dr. Rajesh M Patil[3], Dr. B. G. Nagraja[4]

[1]Research Scholar, Visvesvaraya Technological University, RRC-Belgavi, India, swagatkarve@gmail.com

[2]Research Scholar, Visvesvaraya Technological University, RRC-Belgavi, India, ppc8051@gmail.com

[3]Co-Supervisor, Visvesvaraya Technological University, RRC-Belgavi, India

[4]Professor & Supervisor, Jain Institute of Technology, Devanagere, India

Article History:

Received: *20-06-2023*

Revised: *24-08-2023*

Accepted: *10-09-2023*

Abstract:

This paper is related to the developing an improvised of secured memory efficient cloning detection protocol in WSNs using RSA Algorithm and is used for efficient transfer of data packets with security. NS2 is used as the simulation tool to simulate the outputs. The main aim or objective of the proposed work presented in this paper is to develop a secured memory efficient cloning detection protocol in the mobile adhoc wireless sensor networks. The simulation results shows the effectivity of the methodology that is being proposed by us.

Keywords: WSN, Static, Dynamic, Packets, Authentication, Sensor, Node, Distribution, Network, Key, Message Authentication Code Protocol, Security, Routing, Management, Sink, Cryptography, Source, Energy, Router, Attacker, Base Station, Machine condition monitoring, Industrial wireless sensor networks.

1. Introduction

It is a well-known fact that the WSNs are being used widely & deployed for a large range of applications from monitoring the environment to medical applications, space applications, tracking of objects, etc… In this paper, a routing protocol which is efficient in energy and cloning aware detection procedure is being developed that too in a densely populated area. Here, the WSN developed can detect successful cloning attacks on the WSN and hence the lifetime of the network can be increased [1][2][3].

A ring like structure can be developed and this could be used to facilitate an energy efficient data which can be forwarded along the path towards the sink sensor nodes. The sensor's location information and the witnesses which are there in the WSN can randomly be selected which are located in a ring like structured area in order to verify the legitimacy of the sensor network. In this context, the detected clone attacks can also be detected and reported to the base station. The hubs in the network system needs to transmit the information, it initially sends the solicitation request to the observers (witnesses) for authenticity confirmation, and these witnesses will report an identified assault/attack if the hub node fails to certify in this context [4][5][6].

For productive & efficient detection of the clone & its location, typically, a lot of nodal hubs are chosen, in the sense selected, which are called observers or witnesses, to help confirm the

authenticity of the nodal hubs in the wireless network system. In order to achieve a very good successful rated detection of clone, selection of the witnesses and verification of the legitimacy verification should satisfy 2 important requirements, they are

1. Random selection of the witnesses
2. One witness should successfully receive all theverified messages

for the detection of the clone [7][8][9].

Here, we have used the RSA Algo (Rivest–Shamir– Adleman) which is an algorithm that is used by the current generation computers for encrypting & decrypting of the datas. This RS Algo is used to avoid the collision attacks and device a secured robust clone detection process. As a result of this proposed concept, one can avoid the attacks and eliminate them by the use of some malicious sensornodes. In the work proposed, we have got 100 percent probability detection using trusted witnesses. The secured protocol can achieve a very long network life time by the effective distribution of the traffic load throughout the *m*- WSN [10][11][12].

2. Background work done by the researchers

Quite a number of researchers have worked on the chosen research topic in this paper. Few of them are being addressed here. Y. Xuan, Y. Shen, N.P. Nguyen, and M.T. Thai did some studies on the clone detection protocols & in the literature, this can be classified into two different categories, i.e., centralized and distributed clone detection protocols. In centralized protocols, the sink or witnesses generally locate in the center of each region, and store the private information of sensors. When the sink or witnesses receive the private information of the source node, they can determine whether there is a clone attack by comparing the private information with its pre-stored records. Normally, centralized clone detection protocols have low overhead and running complexity. However, the security of sensors' private information may not be guaranteed, because the malicious users can eavesdrop the transmission between the sink node and sensors. Moreover, the network lifetime may be dramatically decreased since the sensor nodes close to the sink will deplete their energy sooner than other nodes [13][14][15].

The authors, M. Conti, R.D. Pietro, L. Mancini and A. Mei worked on the distributed clone detection protocols, aset of witnesses are selected to match with every sensor which prevents the transmission between the sink and sensors from being eavesdropped by malicious users. There were 3 different types of witness selection schemesin distributed clone detection protocols, viz.,

- deterministic selection,
- random selection, and
- semi random selection.

The deterministic witness selection based clone detection protocols like RED choose the same set of witnesses for all the sensor nodes. By using of the deterministic witness selection, a low communication overhead and a high clone detection probability can be achieved. In addition, the required buffer storage capacityof such protocols is very low, which is only related to the number of witnesses without considering network scale and node density [16][17][18].

In another research work done, a team of networking researchers led by Y. Zeng, J. Cao, S. Zhang, S. Guo and L. Xie did extensive research work on the enhancement of the network security, the distributed clone detection protocols with random witness selection like LSM were proposed in their work, which were closely related to our work. In random witness selection, it is difficult for malicious users to acquire the information of witnesses since the witnesses of each sensor are randomly generated [19][20][21].

However, the randomness of mapping function also increases the difficulty for the source node to reach its witnesses, which makes it challenging to achieve a high clone detection probability. To ensure the clone detection probability, LSM lets all the nodes in the route between source and witnesses store the private information of the source node, which leads to a high requirement of data buffer and energy consumption. Thus, it is essential to guarantee the clone detection probability with low energy consumption and required buffer storage in clone detection protocols with random witness selection approach [22][23][24].

Research engineers, M. Zhang, V. Khanapure, S. Chen and X. Xiao did an extensive research on the distributed clone detection protocols, such as Parallel Multiple Probabilistic Cells (P-MPC) & the quad let proposed a semi-random witness selection approach trying to combine the advantages of both random and deterministic witness selection approaches. In this kind of witness selection scheme, a deterministic region is generated for the source node according to the mapping function, and then witnesses of the source node will be randomly selected from the sensors in this region. However, the two-phases witness selection and randomness of the witnesses for each sensor leads to a high overhead and time complexity. The energy consumption and the required buffer storage of such protocols are lower than the random witness selection approach but higher than the deterministic ones [25].

3. Existing System

In most of the existing clone detection protocols such as Randomized Efficient and Distributed protocol (RED) and Line-Select Multicast protocol (LSM), the required buffer storage size depends on the network node density, i.e., sensors need a large buffer to record the exchanged information among sensors in a high-density WSN, and thus the required buffer size scales with the network node density. Such requirement makes the existing protocols not so suitable for densely-deployed WSNs. Most existing approaches can improve the successful clone detection at the expense of energy consumption and memory storage, which may not be suitable for some sensor networks with limited energy resource and memory storage. Quite a number of dis-advantages exist, to list, some of them are

- High energy consumption
- More memory storage
- Not be suitable for some sensor networks with limited energy resource and memory storage.
- The required buffer storage of sensors is usually dependent on the node density

4. Proposed System

In order to overcome the drawbacks of the existing system, a new method of securing and avoiding the clone attack is proposed in this paper. Besides the probability of clone detection, also the energy consumption and memory storage in the design of clone detection protocol is considered in the research work, i.e., an energy & memory efficient distributed clone detection routing protocol using some random witness selection concepts are used in the wireless sensor networks. The work done here is applicable to any type of general densely populated sensor nodes that too in multi-hop sensor nets [26][27][28].

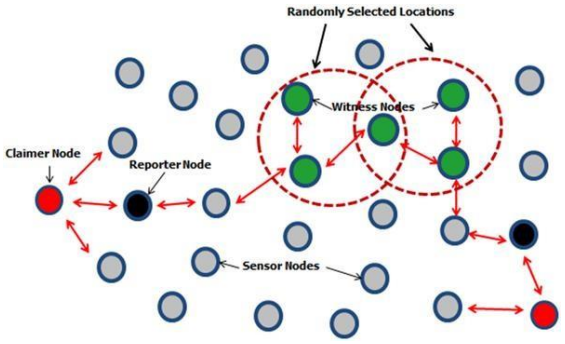


Fig. 1 : Architectural layout of the security in cloning detection WSNs [42]

Adversaries may be required to compromise for the clone sensor nodes for launching of the phishing attacks. An energy efficient *ring type cloning detection* procedure is developed as shown in the Fig. 1 [42], which is done in order to achieve high degree of detection probability. This used some random node selection as the witnesses. At the same time, normal network operations with good network life time can be achieved using this concept where the entire work is being divided into 2 stages, viz., selection of the witness & verification of the legitimacy as shown in the Fig. 2 [42].

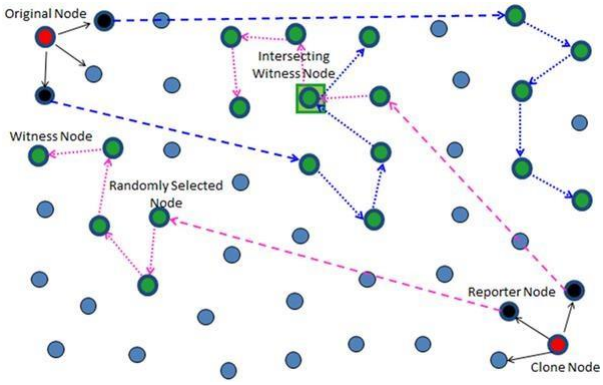


Fig. 2 : Working principle of the security in cloning detection WSNs [42]

In the former case, the source node (S) sends a private info/data to a set of witness nodes, say hello packets and these witness nodes are selected randomly by the use of a mapping function. In the latter case, the verification message along with the private data of the source node (S) will be transmitted to all the witnesses' nodes (W). Suppose if any of the witness node receives the message successfully, the witness node (W) will forward the message to its witness node header

for verification. Once the key (similar to the OTP) is given, it will take the message packet and forward to another, else it will not. This is how the data is secured and the process of legitimate verification is shown in the Fig. 4 [43].

Assumptions:

1. Each sensor node is equipped with a unique RSA key pair.

2. Sensor nodes can communicate with neighboring nodes.

3. Cloning detection is triggered periodically or based on specific events.

Step wise Process

1. RSA Key Generation:

Select two large prime numbers p and q

$$n = p * q$$

$$\varphi(n) = (p-1) * (q-1)$$

Choose an integer e such that $1 < e < \varphi(n)\ and\ gcd(e, \varphi(n)) = 1$

$$d = e\text{^} - 1\ mod\ \varphi(n)$$

Public key (e, n) and Private key (d, n)

2. Message Signing:

M_s = message to be sent

$$S = M\_s\text{^}d\ mod\ n$$

Send (M_s, S) to neighboring nodes

3. Message Verification:

Received (M_s, S)

$$M\_v = S\text{^}e\ mod\ n$$

If $M\_v = M\_s$, the message is verified

4. Memory Usage Optimization:

Let M be the total memory available

Memory used for key storage = $M\_k = 2 * key\ size$

Memory used for message storage = $M\_m = message\ size$

$$M\_u = M\_k + M\_m$$

$$Ensure\ M\_u < M$$

5. Cloning Detection Trigger:

T = Time interval for detection trigger

E = Event-based trigger

$$Detection\ trigger\ =\ Trigger\ detection\ if\ time\ >=\ T$$

Trigger detection if event E occurs

6. Node Communication Overhead:

C = Communication overhead

Number of messages = N_m

$$C\ =\ N\_m\ *\ message\ size$$

Ensure C < maximum allowable communication overhead

7. Detection Accuracy:

$$D_a = \frac{Number\ of\ cloned\ nodes\ detected}{Total\ number\ of\ cloned\ nodes}$$

Optimize parameters to maximize D_a

8. Energy Consumption:

$$E\_t\ =\ E\_s\ +\ E\_v\ +\ E\_c$$

Ensure E_t < maximum allowable energy consumption

5. Procedure

Once the witness node receives the hello data packet message, the witness header will compare the aggregated verified messages with the records which are stored. Suppose if there are multiple copies of verification messages which were received by the witness node, then the clone attack is detected by the node and a revocation process has to be set into action. There are a few existing iterative filter algos, while fundamentally more strong against arrangement collision attacks by the malicious or phishing nodes, than the straightforward averaging techniques, are all things considered susceptive to a novel advanced collision attack concepts we present here in this paper [29][30][31].

An improvement for RSA security algo is proposed in this context by addressing & implementing the security issue. The algo developed could be utilized in getting private & public keys as the RSA algo uses the multiplication of 2 large prime numbers and thus this RSA algo could be used for encryption, decryption as well as for authentication purposes. It has to be noted in this context that the keys that are used for encryption & decryption are both different. One pair of numbers, say (*e*,*N*) is actually called as the public key & is known to all, i.e., public like a global variable [32][33][34].

Memory Efficient Cloning Detection Protocol in Wireless Sensor Networks (WSN) Algorithm:

Secured Memory Efficient Cloning Detection Protocol in Wireless Sensor Networks (WSN): Algorithm Steps with Mathematical Equations

Step 1: Network Initialization

1. Description: Initialize the sensor network with `N` nodes. Each node is assigned a unique ID and a pair of cryptographic keys (public and private).

$$ID\_i = Unique\ Identifier\ for\ Node\ i, Keys(K\_i, K\_i\text{^}\{-1\})$$

where K_i is the public key and K_i^{-1} is the private key of node i.

Step 2: Neighbour Discovery

1. Description: Each node discovers its neighboring nodes and exchanges their IDs and public keys securely.

$$N\_i = \{ ID\_j \mid j \in neighbors\ of\ i \}, \forall\ i \in [1, N]$$

Step 3: Message Authentication

1. Description: Nodes authenticate messages using digital signatures to ensure message integrity and authenticity.

$$M\_i = Message\ from\ node\ i, \sigma\_i = Sign(M\_i, K\_i\text{^}\{-1\})$$

where σ_i is the digital signature of message M_i using the private key K_i^{-1}.

Step 4: Cloning Detection

1. Description: Nodes periodically broadcast their IDs and signatures to their neighbors. Each node verifies the signatures to detect cloned nodes (nodes with duplicate IDs).

$$Verify(\sigma_j, M_j, K_j) \rightarrow \quad Valid\ if\ \sigma_j is\ verified$$

$$Invalid\ if\ \sigma\_j\ fails\ verification$$

where Verify(σ_j, M_j, K_j) is the verification process using node j's public key K_j.

Step 5: Reporting Clones

1. Description: If a cloned node is detected, the detecting node broadcasts a clone report to the network.

$$R\_clone = \{ID\_cloned, \sigma\_cloned\}, \forall\ nodes\ that\ detect\ the\ clone$$

Step 6: Memory-Efficient Storage and Verification

1. Description: Use bloom filters or similar data structures for efficient storage and verification of IDs to save memory.

$$BF = Bloom\ Filter\ for\ storing\ node\ IDs, BF.insert(ID_i) for\ all\ i \in [1, N]$$

where BF.insert(ID_i) adds the ID ID_i to the Bloom Filter.

Another pair of numbers say, (*d*,*N*) is called as the private key or the confidential key and this has to be kept secret at any cost and this will be used for the decryption of the text that had been encrypted with the public keys. Note that our developed algo has 3 important steps, viz., generation of the key, key encryptions & key decryptions. The work proposed has got a wide

number of advantages such as - it achieves high degree of clone detection probability with random witness node selections, can achieve superior performance in terms of the WSN's n/w life time with good data buffering & finally the actual number of buffer storage sensors is independent of the sensor nodes, but will be a function of the hop length of the WSN's radii *h*, i..e, *O*(*h*) [35][36][37].

Probability of clone detection is achieved as follows. Note that in the distributed type of clone detection like the one considered in our work with random witness sensor node selection, the clone detection probability actually refers to whether the witness node can successfully receive the VFN info or not. The probability of clone detection is defined as the probability that the verification info can be transmitted successfully from S to W sensor nodes. In the routing protocol designed, the VFN message is actually broadcasted when it is near the witness node rings in order to guarantee the security of the WSN. It is proved in our case that at least 1 of the witness node could receive the message, viz., the clone attack can be detected with 1 probability. This is how the clone detection is designed in our research work [38][39][40].

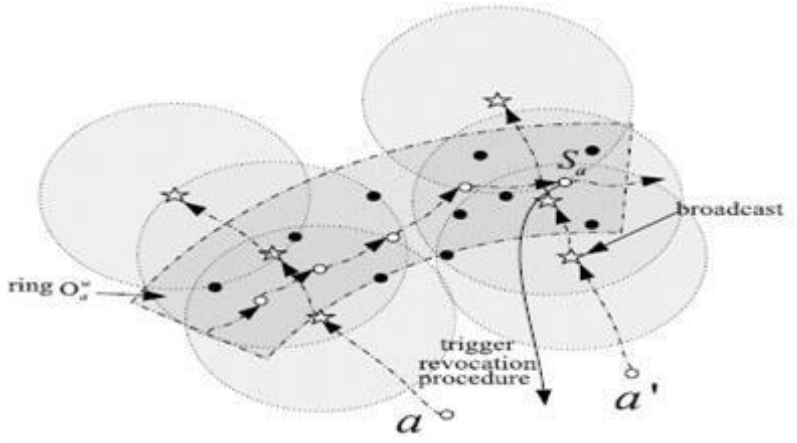


Fig. 4 : Legitimate verification procedure of the S, D, W nodes [33]

6. NS-2 Simulation Results

In this research work, we have proposed a secured memory efficient cloning detection protocol in the mobile adhoc wireless sensor networks using encryption, decryptions keys & by the use of the RS algorithm. The coding (script writing) for the development of a wireless sensor networks for efficient data transfer schemes is developed in the **.**NS2 tool by writing **.**tcl scripts and once it is completed, it is tested for its effectiveness as per the algo steps given below as per the flow chart shown in the Fig. No. 3. The following specs are used in the simulation process. The sensor network of 57 nodes will be deployed in a dimension of (900 × 550) m^2. The source will be located in the centre of the networking field. The transmitting antenna range is 50 meters. It has to be noted that the sensor nodes will be moving in the random direction with a minimum speed of 1 m/s upto 5 m/s. The simulation time interval is taken as 50 ms [41][42][43].

Next, the developed code is saved in a particular folder in the Ubuntu environment. The Ubuntu is started next. At the terminal, commands like sudo –s is being used to enter the kernel. The password is being set. Next, the source code in which the directory / folder is present is

changed using cd command. The developed code is run using ns filename.tcl. The command window of the NS-2 simulator appears with the simulator start button along with the network animator. Once the simulation is started, the node deployment appears on the NS-2 animator screen as shown in the Fig. 4 along with the 2 malicious & attacking phishing nodes. Here, we have taken the value of $n = 57$ with number of active sensor nodes as 55, remaining 2 are the attacker nodes, which can be seen from the Fig. 5 [41].

The proposed algorithm developed is incorporated in the .tcl file in the NS2 environment. The coding is developed in such a way that 57 sensor nodes are deployed in the network similar animator window, the code pattern can be observed in the flow chart shown in the figure 3. The data transfer starts from the source node by sending "*hello*" packets to the sink via the nodes as shown in the Figs. 5 – 9 respectively. Once the data transfer starts, attacker nodes starts attacking in the middle & starts to steal the information by using phishing nodes, but the proposed algorithm immediately identifies which nodes has been attacked by the attacker, ensures the keying is done in a proper manner and immediately makes the effect of attacking node on the attacked node ineffective and the normal process of the data packet transfer starts [41].

In the work considered, first verification of the keys is done first step by step starting from $n = 2$ & ending with $n = 55$. Simulation takes couple of minutes, passes different stages of data packets [44][45][46]

- sending,
- verification,
- encryption,
- decryption,
- cloning,
- witness node selection,
- witness node header selection,
- key verification process

until the sink or destination node. The simulation step size is taken as 50 ms. Once the data transfer is fully successful, the final step is to observe the simulated results from the NAM window command prompt by using the commands chmod 777 results.sh & running the shell script ./results.sh & the plots of throughput, packet delivery, packets drop, etc… are plotted & the results are analyzed from which we can come to a conclusion that the proposed work done is better compared to the others, thus establishing the supremacy of the proposed work [47][48][49].

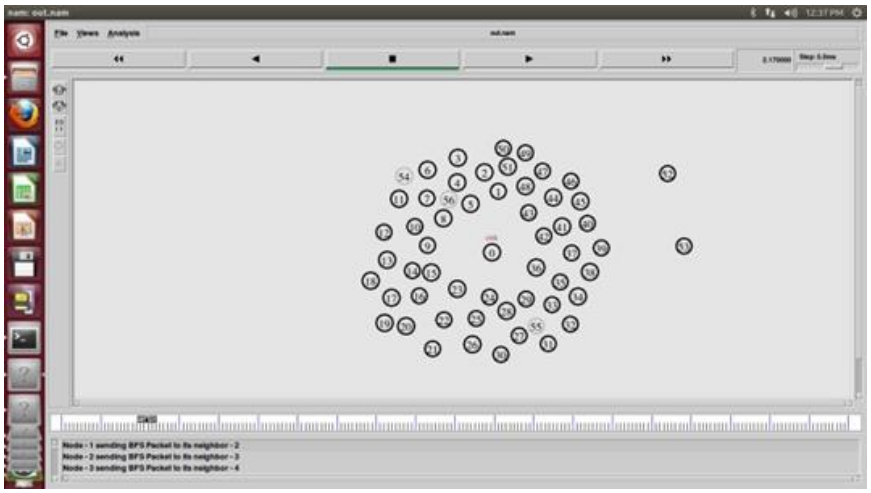


Fig. 5 : Initial deployment of the 57 nodes with the 2 attacking or malicious nodes (52 & 53)

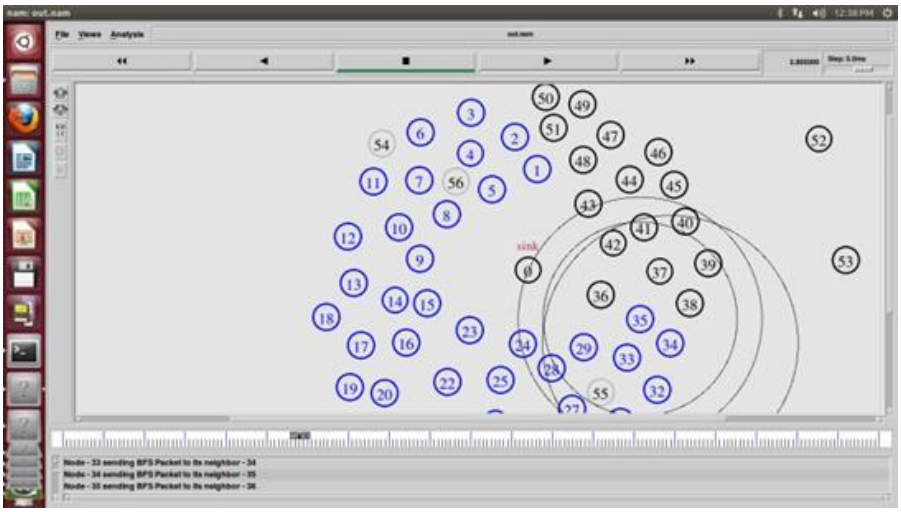


Fig. 7 : Some of the nodes acting as the witness nodes

Fig. 8 : Some of the nodes acting as Head-Witness along with attacker nodes dropping off the data packets

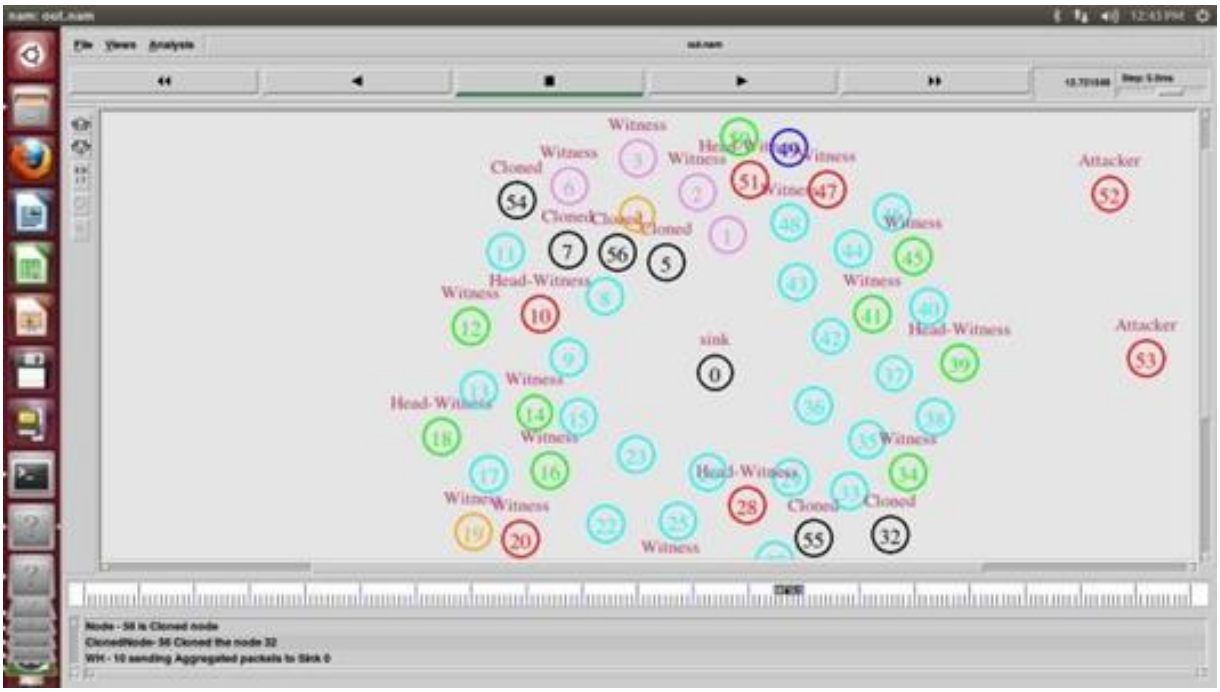
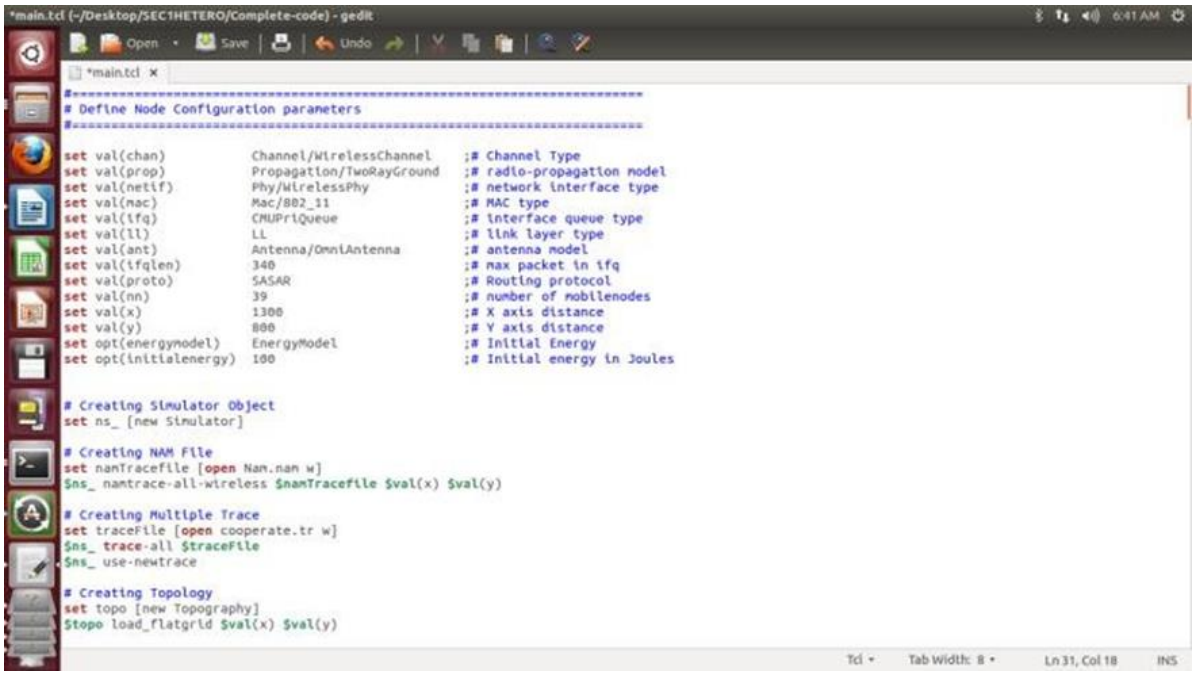


Fig. 9 : Some of the nodes that have been cloned during the process of attack by the malicious nodes (Cloned nodes shown in the black color)



```
#=====================================================================
# Define Node Configuration parameters
#=====================================================================

set val(chan)           Channel/WirelessChannel    ;# Channel Type
set val(prop)           Propagation/TwoRayGround   ;# radio-propagation model
set val(netif)          Phy/WirelessPhy            ;# network interface type
set val(mac)            Mac/802_11                 ;# MAC type
set val(ifq)            CMUPriQueue                ;# interface queue type
set val(ll)             LL                         ;# link layer type
set val(ant)            Antenna/OmniAntenna        ;# antenna model
set val(ifqlen)         340                        ;# max packet in ifq
set val(proto)          SASAR                      ;# Routing protocol
set val(nn)             39                         ;# number of mobilenodes
set val(x)              1300                       ;# X axis distance
set val(y)              800                        ;# Y axis distance
set opt(energymodel)    EnergyModel                ;# Initial Energy
set opt(initialenergy)  100                        ;# Initial energy in Joules


# Creating Simulator Object
set ns_ [new Simulator]

# Creating NAM File
set namTracefile [open Nam.nam w]
$ns_ namtrace-all-wireless $namTracefile $val(x) $val(y)

# Creating Multiple Trace
set traceFile [open cooperate.tr w]
$ns_ trace-all $traceFile
$ns_ use-newtrace

# Creating Topology
set topo [new Topography]
$topo load_flatgrid $val(x) $val(y)
```

Fig. 10 : Structure of the main program “main.tcl” showing the syntaxes, blue shows the steps involved in the development of the code

The simulation result shown in the Fig. 11 gives a brief idea about the life of the network vs. the number of nodes in the wireless sensor network. The proposed work (red colour) is compared with the work done by the other authors by using the MPCL protocol (green colour) which shows that our method is far better than MPCL method, thus showing the profoundness of our

method. The network life time (months) is excellent compared to the other methodology [50][51].

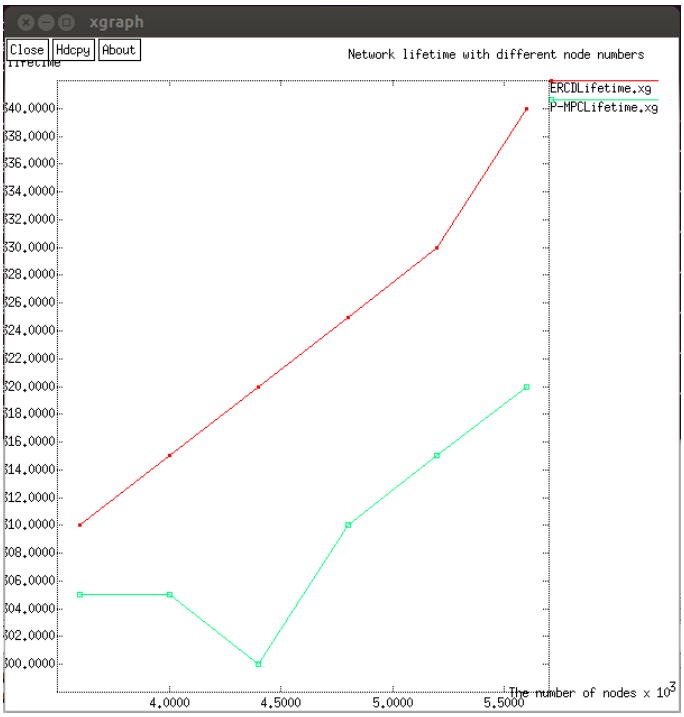


Fig. 11 : Plot of network life time with different sensorcode numbers vs. the no. of nodes

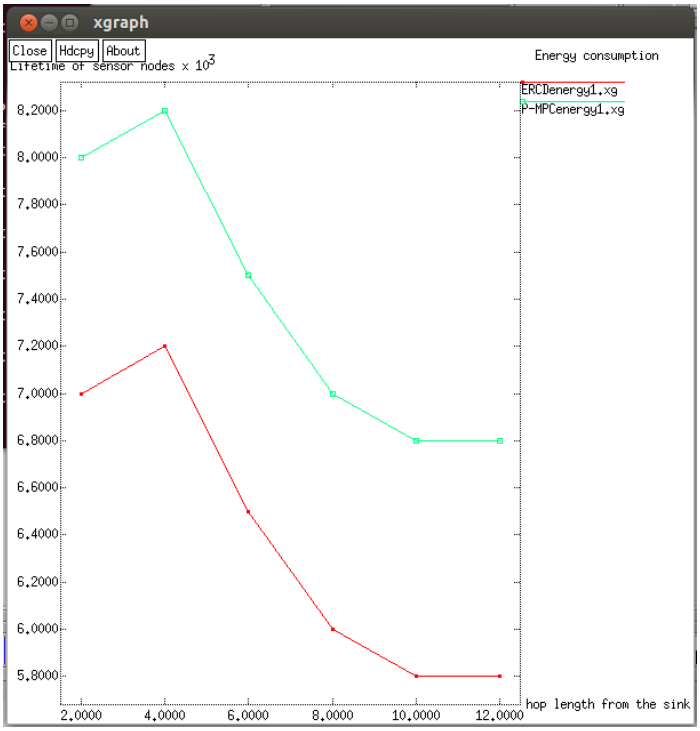


Fig. 12 : Plot of average energy vs. the hop length from thesink node

The simulation result shown in the Fig. 12 gives the graph of average energy vs. the hop

length from the sink in the wireless sensor network. The proposed work (red colour) is compared with the work done by the other authors by using the MPCL protocol (green colour) which shows that our method is far better than MPCL method, thus showing the profoundness of our method. The average energy consumption is excellent, very low compared compared to the other methodology. It shows that the hop length from the sink node increases, the energy consumption of the proposed method decreases far better than the other method [4][5][6].

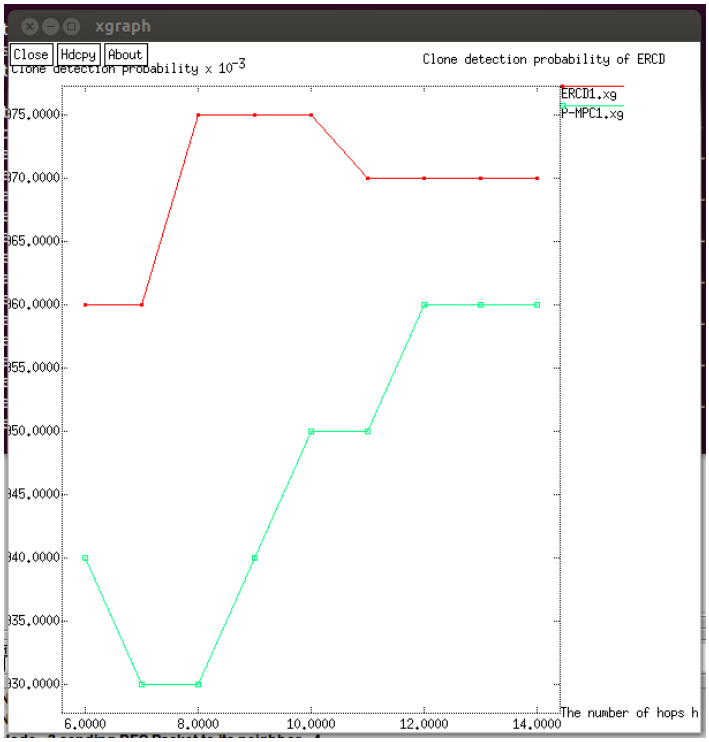


Fig. 13 : Plot of the clone detection probability vs. the number of hops

The simulation result shown in the Fig. 13 gives the graph of clone detection probability vs. the number of hops in the wireless sensor network. The proposed work (red colour) is compared with the work done by the other authors by using the MPCL protocol (green colour) which shows that our method is far better than MPCL method, thus showing the profoundness of our method. The probability of the clone detection in the proposed method is very significant, very high compared to the other methodology. It shows that the number of hops from the sink node increases, the clone detection probability varies but is more significant than the other method [1][2][3].

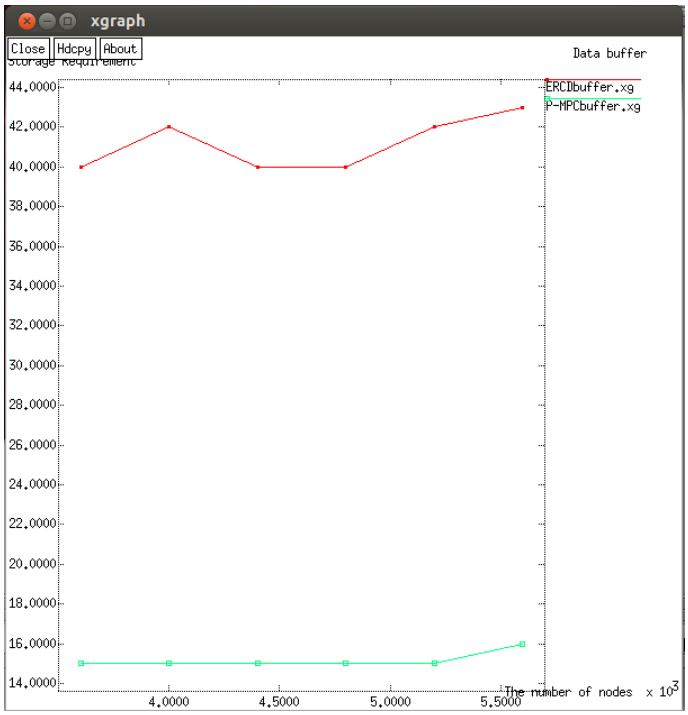


Fig. 14 : Plot of the data buffering vs. the number of nodes in the wireless sensor network

The simulation result shown in the Fig. 14 gives the graph of data buffering vs. the number of nodes in the wireless sensor network. The proposed work (red colour) is compared with the work done by the other authors by using the MPCL protocol (green colour) which shows that our method is far better than MPCL method, thus showing the profoundness of our method. The data buffering or the storage requirement in the proposed method is very significant, very high compared to the other methodology. It shows that the data buffering is varying, but very high compared to the other method [7][8][9].

7. Conclusions

In this paper, the development of secured memory efficient cloning detection protocol in adhoc mobile wireless sensor networks using RS algorithm is presented. Simulation was carried out for 50 ms & 4 performance characteristics were plotted. From the performance characteristics of the network life time with different sensor code numbers vs. the no. of nodes, average energy vs. the hop length from the sink node, clone detection probability vs. the number of hops, data buffering vs. the number of nodes in the wireless sensor network, it can be observed that the proposed system is faring better compared to the work done by others, thus showing the efficacy of the methodology developed by us. A routing protocol which is efficient in energy and cloning aware detection procedure is being developed that too in a densely populated areas. The main application of the WSN routing protocol developed can detect successful cloning attacks on the WSN and hence the lifetime of the network can be increased, which could be observed from the simulated results.

References

[1] S. Agrawal, R. Roman, M. L. Das, A. Mathuria, J. Lopez, "A novel key update protocol in mobile sensor networks",*Proc. 8th Int. Conf. ICISS*, Vol. 7671, pp. 194–207, 2012.

[2] C. Schurgers and M.B. Srivastava, "Energy efficient routing in wireless sensor networks", *MILCOM Proceedings Communications for Network-Centric Operations:Creating the Information Force*, ISBN : 0-7803-7225-5, pp. 1- 5, August 2002.

[3] T. Hayes and F.H. Ali, "Location aware sensor routingprotocol for mobile wireless sensor networks", *IET Wireless Sensor System*, ISSN 2043-6386, pp. 49-57, Jan. 2016.

[4] M. Kalantari and M. Shayman, "Energy efficient routing inwireless networks", *CISS*, pp. 1- 15, March 2004.

[5] N.A. Pantazis, S.A. Nikolidakis and D.D. Vergados, "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey", *IEEE Communications Surveys & Tutorials*, Vol. 15 , Issue 2, pp. 551- 591, 2nd Quarter 2013.

[6] G. Kaur, "Reliability of wireless sensor networks", *International Journal of Advanced Research in Computer Engineering & Technology* (IJARCET), Vol. 3, pp. 1926-1928, May 2014.

[7] C. Karlof and D. Wagner, "Secure Routing in wireless sensor networks: attacks and countermeasures", *Proceedings of the First IEEE International Workshop on SensorNetwork Protocols and Applications*, ISBN: 0-7803-7879-2, pp.293-315, Jun. 2003.

[8] A.S. Pathan, H.W. Lee, C.S. Hong, "Security in WSNs: Issues & Challenges", *ICACT2006, MIC and ITRC Project ISBN 89- 5519-129-4*, 20-22, pp. 1043-1048, Feb. 2006.

[9] M.U. Aftab, O. Ashraf, M. Irfan *et.al*., "A review study of wireless sensor networks and its security", *Journal of Communications and Network, SciRes*, pp. 172-179, Oct. 2015.

[10] P. Sherubha and M.M Priya, "A detailed survey on security attacks on wireless sensor network and its communication", *Int. Journal of Soft Computing*, Vol. 11, No. 3, pp. 221-226, ISSN: 1816-9503, 2016.

[11] N.A. Alrajeh, S. Khan, B. Shames, "IDS in wireless detector networks : A Review", *Int. Journal of Distributed Detector Network*, pp. 1-7, April 2013.

[12] G. Kalpana, T. Bhuvaneswari, "A Survey on Energy Efficient Routing Protocols for Wireless Sensor Networks", *2nd National Conference on Information andCommunication Technology* (NCICT), 2011.

[13] Mohammad Masdari1 and Maryam Tanabi, "Multipath Routing protocols in Wireless Sensor Networks: A Surveyand Analysis", *Int. Jour. of Future Generation Communication and Networking* Vol. 6, No. 6, pp.181-192, 2013.

[14] K. Vinoth Kumar, S. Karthikeyan, "Multi-hop Energy Efficient Reliable and Fault Tolerant Routing Protocol for Wireless Sensor Networks", *Int. Jour. of Emerging Tech. &Advanced Engg, IJETAE*, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 2, February 2013.

[15] Ning Sun, Young-bok Cho, Sang-ho Lee, "A Distributed Energy Efficient and Reliable Routing Protocol for Wireless Sensor Networks", *IEEE International Conference on Computational Science and Engg.*, CSE/I-SPAN 2011.

[16] Ali Norouzi, Faezeh Sadat Babamir, Abdul Halim Zaim, "A Novel Energy Efficient Routing *Protocol in Wireless Sensor Networks*", IEEE 2011.

[17] Satvir Singh, Meenaxi, "A Survey on Energy Efficient Routing in Wireless Sensor Networks", *IEEE Transactions*,Vol. 3, Issue 7, July 2013.

[18] Monica R Mundada, Savan Kiran, Shivanand Khobanna, Raja Nahusha Varsha and Seira Ann George, "A study on energy efficient routing protocols in wireless sensor networks", *International Journal of Distributed and ParallelSystems* (*IJDPS*) Vol. 3, No. 3, May 2012.

[19] Ahmed Ali Saihood, Rakesh Kumar, "Enhanced Location Based Energy-Efficient Reliable Routing Protocol for Wireless Sensor Networks", *International Journal of Inventive Engineering and Sciences* (*IJIES*) ISSN: 2319–9598,Volume-1, Issue-6, May 2013.

[20] S. Gupta and K.C. Roy, "Comparison of different energy minimization techniques in wireless sensor network," *International Journal of Computer Applications*, Vol. 75, No. 18, pp. 20–26, 2013.

[21] N.A. Pantazis, S.A. Nikolidakis, and D.D. Vergados, "Energy efficient routing protocols in wireless sensor networks: a survey," *IEEE Communications Surveys & Tutorials*, Vol. 15, No. 2, pp. 551–591, 2013.

[22] Muhammad Nadeem Akhtar, Arshad Ali, Zulfiqar Ali, Muhammad Adnan Hashmi, Muhammad Atif, "Cluster Based Routing Protocols for Wireless Sensor Networks: An Overview*", International Journal of Advanced Computer Science and Applications* (IJACSA), Vol. 9, No. 12, 2018.

[23] Singh S.K., Singh M.P. & Singh, Dharmendra, "A survey of energy-efficient hierarchical cluster-based routing in wireless sensor networks", *International Journal of Advanced Networking and Appn.* (*IJANA*), Vol. 2, pp. 570-580, 2010.

[24] Bilal Jan, Haleem Farman, Huma Javed, Bartolomeo Montrucchio, Murad Khan and Shaukat, "Energy Efficient Hierarchical Clustering Approaches in Wireless Sensor Networks: A Survey", *Hindawi Wireless Communications and Mobile Computing*, Vol. 2017, Article ID 6457942, 14 pages, 2017.

[25] Method Gajendran Malshetty, Basavaraj Mathapati, "WSN Clustering Based on EECI (Energy Efficient Clustering using Interconnection)", *International Journal of Innovative Technology and Exploring Engineering* (*IJITEE*), *Published By: Blue Eyes Intelligence Engineering & Sciences Publication*, ISSN: 2278-3075, Vol. 9 Issue 1, pp. 3564, Madhya Pradesh, India, Nov. 2019.

[26] Pavithra G.S., Babu N.V., "Energy Efficient Hierarchical Clustering using HACOPSO in Wireless Sensor Networks", *International Journal of Innovative Technology and Exploring Engineering* (*IJITEE*) ISSN: 2278-3075, Vol. 8 Issue 12, pp. 5219-5225, October, 2019.

[27] Thesiya Khushbu , Viraj Daxini, "Novel Clustering Approach to Reduce Energy Consumption in Wireless Sensor Network based on LEACH", *International Journal of Computer Science and Mobile Computing*, Vol. 4 Issue 6, pg. 945-953, Jun. 2015.

[28] A. Babu Karuppiah, J. Dalfiah, "An Improvised Hierarchical Black Hole Detection Algorithm In Wireless Sensor Networks", *IOSR Journal of Electronics and Communication Engineering* (*IOSR-JECE*) e-ISSN: 2278-2834,p- ISSN: 2278-8735, (ICEICT 2016), Second International Conference on Electrical, Information and Communication Technology, pp. 134-141, 2016.

[29] Ganesh, "Efficient and secure routing protocol for wireless sensor network", *Ph.D. Thesis*, *Sathyabama University*, Jeppiaar Nagar, Chennai-119, India, August 2014.

[30] Rajesh Kumar Varun, R.C. Gangwar, "Hierarchical Energy Efficient Routing in Wireless Sensor Networks and its Challenges", *International Journal of Engineering and Advanced Technology* (*IJEAT*), ISSN: 2249 – 8958, Vol. 9 Issue1, pp. 4024-4027, Oct. 2019,

[31] Anil. G.L, J.L. Mazher Iqbal, "Implementation of Secure Energy Efficient Network Priority Routing (SEENPR) Protocol with Secure Key Management in WSN", *International Journal of Recent Tech. and Engg.* (*IJRTE*), ISSN: 2277-3878, Vol. 8, Issue 2S11, pp. 3096-3103, Sep. 2019.

[32] Anand Nayyar, "Improvised Energy Efficient Routing Protocol based on Ant Colony Optimization (ACO) for Wireless Sensor Networks", *Ph.D. Thesis, Department of Computer Science Desh Bhagat University*, Mandi Gobindgar, Punjab, 2017.

[33] Musheer Vaquar, Sanjay Kumar Agarwal, "HETRP: High Energy Efficient Trustable Routing Protocol for Wireless Sensor Network International", *Journal of Innovative Technology and Exploring Engineering* (*IJITEE*), ISSN: 2278- 3075, Vol. 9 Issue 3, pp. 1034-1042, Jan. 2020.

[34] S. Ganesh and R. Amutha, "Efficient and Secure Routing Protocol for Wireless Sensor Networks through Optimal Power Control and Optimal Handoff-Based Recovery Mechanism", *Hindawi Publishing Corporation's Journal of Computer Networks and Communications*, Vol. 2012, Article ID 971685, 8 pages , 2012.

[35] Anil. G.L, J.L. Mazher Iqbal, "Implementation of Secure Energy Efficient Network Priority Routing (SEENPR) Protocol with Secure Key Management in WSN", *International Journal of Recent Technology and Engineering* (*IJRTE*), ISSN: 2277-3878, Vol. 8, Issue 2S11, pp. 3096 – 3103, Sep. 2019.

[36] Qu Y., Zheng G., Wu H., Ji B. & Ma H., "An Energy- Efficient Routing Protocol for Reliable Data Transmissionin Wireless Body Area Networks", *Journal of Sensors, Basel,Switzerland)*, Vol. 19, No. 19, pp. 4238. 2019.

[37] Rajdip Pau & Banani Das, "A Survey on Energy Efficient Routing Techniques and Security Measures in Wireless Sensor Network", *Conf. Paper*.

[38] Muhammad Kamran Khan, Muhammad Shiraz , Kayhan Zrar Ghafoor, Suleman Khan, Ali Safaa Sadiq and Ghufran Ahmed, "EE-MRP: Energy-Efficient Multistage Routing Protocol for Wireless Sensor Networks", *Hindawi Wireless Communications and Mobile Computing*, Vol. 2018, Article ID 6839671, 13 pages, 2018

[39] K. Nattar Kannan and B. Paramasivan, "Development of Energy-Efficient Routing Protocol in Wireless Sensor Networks Using Optimal Gradient Routing with On Demand Neighborhood Information", *Hindawi Publishing*

Corporation's International Journal of Distributed Sensor

Networks, Vol. 2014, Article ID 208023, 7 pages, 2014.

[40] Yogini Anant Patil, Rahul Gaikwad, "A Study on Enhanced Energy-Efficient and Reliable Routing for Mobile Wireless Sensor Networks with authentication", *International Journal of Innovative Research in Computer and Communication Engineering*, ISSN(Online): 2320-9801, ISSN (Print): 2320-9798, Vol. 5, Issue 1, pp. 259-263, Jan. 2017,

[41] R. Logeswari & V. Manimaran, "A Survey on Secure and Energy Efficient Routing in Wireless Sensor Networks", *International Journal of Latest Engg. Science* (*IJLES*) E-ISSN:2581-6659, Vol. 3, IJLES pp. 9-20, Issue 1, Jan – Feb. 2020.

[42] Zhongming Zheng, Anfeng Liu, Lin X. Cai, Zhigang Chen, Xuemin (Sherman) Shen, "Energy and Memory Efficient Clone Detection in Wireless Sensor Networks", *IEEE Transactions on Mobile Computing*, Vol. 15, No. 5, Jan. 2015.

[43] Wazir ZadaKhan, Mohammed Y. Aalsalem, N.M. Saad, "Distributed Clone Detection in Static Wireless SensorNetworks : Random Walk with Network Division", *PLOS ONE Journal*, Taiwan, pp. 1-22, May 18, 2015.

[44] E. Sujatha, R. Christy Priya, N. Kanimozhi, L. Joys Kiruba,

D. Deborah, "Energy and Memory Efficient Clone Detection in Wireless Sensor Networks", *International Journal of Advanced Research Trends in Engineering and Technology* (*IJARTET*), Vol. 3, Special Issue 19, April 2016.

[45] Heesook Choi, Sencun Zhu, Thomas F. La Porta "SET: Detecting node clones in sensor networks", *Security and Privacy in Communications Networks and the Workshops, Third International Conference on Secure Communications*, pp.341–350, IEEE. 2007.

[46] W. Lou and Y. Kwon, "H-Spread: A Hybrid Multipath Scheme for Secure and Reliable Data Collection in Wireless Sensor Networks," *IEEE Trans. Vehicular Technology*, Vol.55, No. 4, pp. 1320- 1330, Jul. 2006.

[47] T. Shu, M. Krunz, and S. Liu, "Secure data collection in wireless sensor networks using randomized dispersive routes," *IEEE Transactions on Mobile Computing*, Vol. 9, No. 7, pp. 941–954, Jul. 2010.

[48] Y. Zeng, J. Cao, S. Zhang, S. Guo, and L. Xie, "Random- walk based approach to detect clone attacks in wireless sensor networks," *IEEE Journal on Selected Areas in Communications*, Vol. 28, No. 28, pp. 677–691, Jun. 2010.

[49] R. Brooks, P.Y. Govindaraju, M. Pirretti, N. Vijaykrishnan, and M.T. Kandemir, "On the detection of clones in sensor networks using random key pre-distribution," *IEEETransactions on Systems, Man, and Cybernetics*, Vol. 37, No.6, pp. 1246–1258, Nov. 2007.

[50] M. Zhang, V. Khanapure, S. Chen, and X. Xiao, "Memory efficient protocols for detecting node replication attacks in wireless sensor networks," *Proc. IEEE ICNP, Princeton, NJ, USA*, pp. 284–293, Oct. 13-16 2009.

[51] Avneet Kaur, P.S. Mann, "Detection of Clone Attacks In Wireless Sensor Networks: A Survey", *International Journal of Research in Computer Applications & Robotics*, Vol. 2, pp.49-57, 2014.