Performance Analysis of Cluster Based Protocols in Sensor Networks and their Vulnerabilities

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ABSTRACT: Wireless sensor networks as gained lots of impact in the real time applications like monitoring, surveillances and tracking. These applications are mainly rely on the collection of critical information where manual information collection is very difficult task. WSNs are more vulnerable to many types of threats, providing security will be very complex due to the resource constraint sensors. The proposed work aims to study and analyze the vulnerabilities and its effect on the performance of sensor networks in cluster based routing protocols. An exhaustive analysis is presented by captivating the standard clustering architecture with its different stage of operating modes. A comparison is done for with latest existing security solutions which mainly deal with cluster based protocols in wireless sensor networks. An Open Systems Interconnection layer wise comparison is presented with the possible vulnerabilities at each layer. This work also enlightens the literal need of security and its requirements in wireless sensor networks for an efficient information system.

KEYWORDS: Vulnerability; Threats; Security Requirements; Security Challenges; Clustering; Confidentiality; Integrity; Authentication; Data freshness;

I. INTRODUCTION

God has created humans with five sensors, but humans are created more than 50 basic sensors which can sense parameters like, odour, taste, electric charges and many. As trends in sensor technology is emerging, its applications also gaining lots of impact in real world. Wireless sensor networks (WSNs) are one of the most prominent communication technology built over these sensors. WSNs are the networks of limited resource nodes with some wireless link. These nodes are deployed in human unattended areas where collection of information is very necessary and difficult [1] [2]. Due to its wireless nature which operates on low frequency channel it is more vulnerable to wide range of attacks. The major security requirements in wireless sensor networks are confidentiality, integrity, authentication and availability. The attacks on the these networks can be from inside or outside where inside attacks is due to malfunctioning of the original nodes and outside attacker [3][4]s are due to deployment a malicious nodes[5] which can easily communicate with other types of nodes.
Security in WSNs has gained lots of important in recent WSNs research [6]. Many researchers had contributed ideas in proposing solutions and effective defences against many attacks [7-13]. WSNs has a wide range of applications in the future while contributing in the field of Internet of Things and Big Data for many real time application[14] and data analysis for many social and security applications.

1.1. Need of Security in WSNs[15]: As the major application so these WSNs is collection of information during monitoring environmental changes and battle field surveillance, but security in necessary only in some critical applications.

Security in battle field surveillance in very crucial as the attacker can malfunction the internal node and can also deploy the malicious nodes. These operations may lead to loss of critical information by Intercepting, Modifying and fabricating the message sent by original nodes [16]. In some applications the attackers may try only to destroy the monitoring system without concentration on the message by tampering the nodes or by attacking on the physical layer of the nodes.

1.2. Security Challenges: There are many hindrance and constraints involved when designing a security protocol for WSNs. The limited memory, storage, processor capabilities and harsh environmental conditions may restrict the researchers for providing security protocols. The summarization of the security challenges in sensor networks from some research article [7][17][18] is as follows:

- Providing the necessary security requirements by minimizing the resource consumption of the nodes
- Concentrating on the security solutions suitable for particular types of applications
- Aiming to maintain the performance of the developed security protocols

II. RELATED WORK

This section focuses on analyzing the performance and vulnerability of the clustering protocols. First a discussion of clustering is made for studying the working mechanism of the clustering in WSNs [19].

2.1. Clustering Protocols: This is promising protocol which can be used for efficient information transfer in WSNs[20], this include data aggregation, distributed data collection, hop by hop message transfer. These factors made the clustering protocol to use the resources of the nodes very efficiently and increase the lifetime of the networks. Currently there exists many clustering protocol which operates on different factors as discussed bellow.

2.1.1. Operation Modes of Clustering: All the clustering protocols are mainly operated on 2 phases, setup phase and steady phase. Many researchers have proposed different way of phase operation; some of them are discussed here.

2.1.2. Different Setup phases: In this phase there will be formation of cluster head and cluster through advertizing. The node which is selected as cluster head will broadcast the message to its surrounding nodes for joining its cluster, based on the signal strength the node will decide to become its member. There are various criteria for selecting the cluster head like-random selection, based on high energy, based on the density of nodes. This clustering will reduce the energy consumption of the nodes by avoiding redundant data, reducing communication distance i.e. instead of nodes send their data to base station it can be grouped in-between and transferred to base station via cluster head.

2.1.3. Different steady Phase: This phase mainly contribute how to transfer the data. This phase includes direct data transfer to base station and indirect data transfer to base station via cluster head. This phase included hop by hop data transfer with an optimum path selection.

Low Energy Adaptive Clustering Hierarchy (LEACH) [21] the most popular cluster based protocol. Based on the LEACH many protocol were proposed by adding additional features and different operation modes like REBCH [22], EECH [23], HEED [24], and QIBECC [25] were proposed with different way of selecting of cluster head, formation of clusters, data aggregation.
The operating nature of clustering protocol had gained lots of impact in efficient power utilization for increasing the lifetime of the nodes. But it is very vulnerable for many threats as its relay on cluster heads for data aggregation and routing, if the attacker malfunctioned or destroy these heads means there will be no assurance for the originality of the information.

### III. Vulnerability Analysis in Clustering Protocols

One of the major vulnerabilities in WSNs is due to the deployment of sensors which are scattered in insecure place and the wireless nature makes it more prone to attacks. This section identifies the vulnerabilities and threats in each Open Systems Interconnection (OSI) layer.

#### 3.1. Physical Layer Vulnerabilities:
Once the cluster head is selected it sends a request to its surrounding for forming a cluster through advertising itself. This advertising may be received by malicious nodes and may create traffic causing interference at the cluster heads. This leads to more power dissipation from the cluster heads and reduce the network lifetime. Another type of attack can be tampering the nodes and make it useless.

#### 3.2. Data Link Layer Vulnerabilities:
This layer is the major layer of OSI which is more prone to attacks and there is a need of countermeasures to secure it. The main vulnerability is the broadcast and multicast message transfer; this can affect the confidentiality of the information. The information transmitted from one node can be easily received by others. If the information sent from cluster heads is not kept confidential means the whole system can be insecure as the cluster head have the aggregated information.

#### 3.3. Network Layer and Transport Layer Vulnerabilities:
This layer is mainly vulnerable during the data transmission phase. The information transmitted by cluster head may not reach the base station via trusted hop. This may cause the loss of information or delay in the transmissions which make the system halt. This vulnerability may also contribute to more energy dissipation of the cluster head. The intruder may manages to become cluster head which may receives information from the members and send false packets to other hops and base station. However, because it is a cluster based protocol

These vulnerabilities in clustering can be reduced using some of the general counter measure as discussed in [1] using Channel hopping, Blacklisting, CRC, Encryption and Decryption. There are some specific methods which mainly focus on the some of the key concepts as discussed below.

**SLEACH [27]:** is the first security enhanced implementation over LEACH. This protocol made a analysis on the security issues in cluster based protocols for a resources constraints devices.
Sec-LEACH [28]: This protocol provides an efficient secure clustering by implementing additional features to LEACH for providing cluster based security. This protocol uses a random-key distribution with a fixed pool of key and μTESLA for hierarchical clustering in WSNs with dynamic cluster formation. Based on this key distribution it tries to identify the malicious nodes.

FLEACH [29]: Provides a secured peer to peer information transfer in LEACH based protocol by using a random key per-distribution with symmetric key cryptography to improve the security features in cluster based protocol.

3.4. Novel Approach for Secured Communication in WSN Using Dynamic Low-Weight Keys [NPSC] [30]: A hierarchical protocol based on LEACH for heterogeneous networks is proposed in [30], using a dynamic low weight keys. A pair of keys is assigned to each pair of the nodes called two way keys. In associated a cluster head will use the common key to communicate with bases station with a manufacturing code. This protocol made some assumption like Base station has no resource constraints; network is heterogeneous where high security nodes are used as trusted nodes which can also withstand tampering attacks. A unique code called Manufacturing Code and a Hash code is used as the private key of length 64 bits. This protocol is designed to withstand the 4 threats i.e. Threat0, Threat1, Threat2 and Threat3 caused by the malicious nodes.

- Threat0 malicious node can be restricted using time validation process of hello packets.
- Threat1 can be prevented using the allocation time of the cluster head.
- Threat2 is prevented using the above 2 process with a secret key matching techniques
- Threat3 node is restricted using all 3 processes with hash code of the particular node with base station.

3.5. CIAWSNs protocol for Secure Information Transmission [31]: A light weight key without distribution techniques is proposed in our previous work [31] called as CIAWSNs, focused on providing a simple low complex secure mechanism for resource constrained WSNs. Using this on the basic security requirements of the WSNs is achieved with an optimal resource usage. This protocol also has some security level assumptions. It assumes that during initial deployment there will be no malicious nodes in the network. Some numbers of malicious nodes are used for create attacks in the networks. These malicious nodes are functioned only to send the false information, packet sniffing and to make hello attack. This protocol operates only on some set of firewall rules, device identification and key compression at the cluster head for maintaining data confidentiality.

This protocol is resistance to the following attacks:

- Eavesdropping: Ensuring confidentiality of the information in WSNs
- Packet Sniffing: Ensuring integrity of the message transferred from cluster heads
- False Message: Ensuring authentication of the message that it is from genuine source.

Comparisons between the protocols were made to analyse the energy utilization by the nodes in the network while achieving security requirements. Figure-2 shows the lifetime of the network where the NPSC [30] is compared with LEACH which is simulated for 100 numbers of nodes for 800 rounds. The NPSC[30] has implement a secure cryptographic techniques, as a result the protocol is secure but the number of failure nodes is more compared to LEACH which is without security.
Figure-3 shows the lifetime of the CIAWSNs which is also a based on LEACH protocol which is simulated with 100 number of nodes for 800 rounds. This protocol aims to provide security with low complex solutions by using firewall, device identification and key compression. The life time of the nodes is last is 39% where is in figure-2[30] it is 60%. The first node dead is before 300th rounds in figure-2 but in CIAWSNs the first node dead is at around 350th rounds. Using this light weight secure solution the lifetime of the network is increased by 21% compared to [30].

This concludes that using light weight security solution one can improve the performance of WSNs over existing cluster based protocols. Even though in the recent years energy is not a constraints due to harvesting of energy using environmental conditions, but it can reduce the complexity at the node side.

IV. CONCLUSION AND FUTURE WORK

This work aims to analyse the vulnerabilities and security requirements necessary for secure information transfer in Wireless Sensor Networks. These analyses are produced for identifying the vulnerabilities at major Open Source Interconnection (OSI) layers of WSNs with the associated threats. This work mainly focused on analysing the security performance of cluster based protocols with efficient resource utilization. This shows that how secure is the clustering protocols and how it can be enhance for achieving more security requirements. The standard secure cluster based protocols are discussed with their advantages and it is compared with each other for better analysis by considering its...
vulnerabilities. Clustering is one of the best routing protocols in WSNs; hence this work focused to enhance the feature of clustering by identifying its vulnerabilities in providing security for efficient information transfer. The future work of this work can be an implementation of an enhanced secure protocol of CIAWSNs for heterogeneous WSNs by incorporating the analysis done.

REFERENCES

6. Wengen Gu, Xun Wang, Shiyam Chellapappan, Dong Xuan and Ten H. Lai, “Defending against Search-based Physical Attacks in Sensor Networks”, Department of Computer Science and Engineering, The Ohio State University, Columbus, OH 43210, USA.

24. Ossama Younis and Sonia Fahmy, “Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy-Efficient Approach,” Department of Computer Sciences, Purdue University, 250 N. University Street, West Lafayette, IN 47907–2066, USA
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