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"An analytical study on the privacy protection through group key management in non-network"

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Abstract

Group Key Management (GKM) plays a crucial role in maintaining security and privacy in non-network environments, such as Internet of Things (IoT), vehicular ad hoc networks (VANETs), and smart grids. This analytical study reviews recent advancements in GKM protocols from 2019 to 2022, highlighting methods that enhance privacy protection in decentralized systems. GKM protocols aim to efficiently manage cryptographic keys for a group of users, ensuring that only authorized members can access shared resources. The study examines various protocols, focusing on their efficiency, scalability, and robustness against security threats. Key trends include the integration of blockchain technology for decentralized key management, lightweight cryptographic schemes for resource-constrained environments, and dynamic key management approaches that cater to the mobility and heterogeneity of modern IoT devices. This review provides insights into the challenges and future directions in GKM, emphasizing the need for protocols that balance security, privacy, and computational efficiency.

Keywords: - Group Key Management (GKM), Privacy Protection, Non-Network Environments, Internet of Things (IoT), Vehicular Ad Hoc Networks (VANETs)

Introduction

The exponential growth of interconnected devices in various sectors, including IoT, VANETs, and smart grids, has led to increased concerns about security and privacy. Group Key Management (GKM) protocols are essential for securing communications within these groups by managing and distributing cryptographic keys efficiently. These protocols ensure that only authorized members can access and exchange

information securely, preventing unauthorized access and data breaches.

Recent advancements in GKM have focused on improving the efficiency, scalability, and security of these protocols to cater to the diverse and dynamic nature of modern networks. This study aims to analyze the latest developments in GKM from 2019 to 2022, providing a comprehensive overview of the methods used to enhance privacy protection in non-network environments. The review highlights key trends and technologies, such as the adoption of blockchain for decentralized key management, the development of lightweight cryptographic schemes for resource-constrained devices, and dynamic key management strategies that address the mobility and heterogeneity of modern IoT systems.

Group Communication-Related Security Issues

This thesis examines critical security challenges in group communication, such as unicast. Integrity, authentication, accessibility, and confidentiality were all concerns for group communication security service providers. When attacking a multicast transmission, the unicast enemy will carry both active and passive attacks.

- Surveillance of confidential communications
- The group session is upsetting.
- Data transmission is being blocked.
- Injecting fictitious data congestion
- Acting as if you're going to a group session
- Individuals conspiring information and forming a fictitious group session to get unlawful access; group members may have cryptographic keys and other group-related data (or information). As a result, it is critical to communicate (or send) secure data sharing information to the group members.

Group Authentication and Security

In order to provide security services in secure multicast contexts, entity authentication, data integrity, and secrecy are required. The following are some specific requirements for secure multicast group communications:

(a) A host must have its own security requirements for joining particular groups or other groups (for example, who can join the groups), multicast group communication must provide its own security services that are only accessible to authorized members, and the group manager will verify the service provided by.

- Individuals in a group confirm that the service they are receiving is from a legitimate source. Members of the group and the group managers will cross-check each other's identities.

(b) The other two options, static and dynamic, may have different requirements for dealing with group communication keys due to member departs and joins. If backward and forward secrecy is required in a dynamic approach, group keys must be re-keyed anytime there is a change in group membership.

Scalability

In general, scalability refers to a framework's (or design's) ability to scale to a larger number of hosts over a larger physical region while maintaining the same quality of service. By using a single design, you may provide important changes to all of the group members separately (All the members protected by separate key). If the group is large and/or has a very dynamic group membership, scalability challenges for secure group communication should be addressed from the beginning of any key management architecture.

MANET Key Management Schemes Overview

Key Management Schemes with Asymmetric Keys

In recent research articles, numerous key management strategies or systems for MANETs have been proposed. The underlying principle behind most public key encryption is to distribute the CA function among multiple nodes. "A secure key management technique based on threshold cryptography (t, n)." T-1 hacked servers are tolerated by the system" (Zhou and Hass, 1999). "A localized key management method in which all nodes are servers and the certificate service can be provided locally by a set of surrounding nodes." A similar technique was proposed by Yi,

Naldurg, and Kravets" (Luo, Kong, and Zerfos, 2001). Their certificate service is distributed to a selection of nodes that are physically more secure and powerful than the others. 2007 (Wu and Wu) “presented a technique similar to Yi, in which server nodes form a mesh structure and an efficient ticket scheme is used." (J. Hubaux, L. Buttyan, and S. Capkun, 2001) "I examined a fully distributed technique based on the same concept as PGP." (Kravets and Yi, 2002) Provide a logical model of confidence. Their plan was to take advantage of the advantages and disadvantages of both central and entirely dispersed trust structures.

Key Management Schemes with Symmetric Keys

Many research papers have been published that use symmetric-key cryptography to procure MANETs. For sensor nodes that are unable to conduct costly asymmetric cryptographic calculations, a few symmetric key management approaches have been proposed. Keys can be preloaded as a pair or a group of keys into the nodes, depending on the uneven key distribution. "Introduced a distributed symmetric key distribution strategy for MANETs," according to Perring. The essential notion is that each node has a set of keys preloaded from a huge key pool" (Perrig, 2003). The key model must be satisfied with the ownership that at least one common key can be found by a subset of nodes, and that the common key should not be encircled by the neighborhood of a lot of other nodes beyond the subnet For the sensor nodes, Perrig proposed a "symmetric key agreement technique." The main idea behind their method is that each node has a unique key that it shares with a group of other nodes in two dimensions (vertical and horizontal)" (Perrig, 2003). As a result, any combination of hubs can rely on at least one middle hub to construct the basic key.

Key Management Schemes in Groups

MANETs Research areas / regions with combined and group-determined applications will be effective. Group key management (GKM) is one of the most important components of secure group communications. In big and dynamic groups, however, key management is extremely challenging due to security and scalability concerns. For example, anytime a new member joins the group or a prior member leaves the group, the group manager must change the group key to ensure backward and forward

security.

Review of Literature

The literature review focuses mostly on current challenges, security risks, authentication, and prior techniques used to solve inclusive problems.

The GKMP problem is a well-known issue that has been brought to light by various academics and addresses group communication issues in wireless networking. "Due to latency and node failure, fault tolerance is a key negative in asynchronous networks," says the author (Bhargava and Madria, S. K, 2000). Failure detection and repair techniques result in the groups exchanging failure notifications on a regular basis. "In such networks, the overhead is limited by establishing a consistent ring structure with pair wise messages for detecting group communication failures," says the author (Seba, H...FTKM, 2006). Apart from that, security is the primary concern in the cloud environment. In unsecure ad hoc networks, the GKMP approach is treated as a resource-intensive protocol. Without a centralised network, the security of such a network is limited by using a key-based open network. The keys are made in such a way that they alter in accordance with the participants. "An efficient, clean, and secure three-round authenticated group key agreement system that performs well on ad hoc networks," according to the proposal (Augot et.al, 2007). "In a multicast context, an effective protocol with an algorithm." This protocol addresses the overhead difficulties by employing two solutions: the key is produced at the server during each event, and the key is multicast across all groups," according to the proposal (Pour et al, 2007). "A multilayer security and a decentralised group key management architecture that reduces overhead, as well as avoiding single point failure employing better resilience problem," according to the proposal (Huang and Medhi, 2008). Over groups, a secure roaming protocol is implemented without the use of fresh keys. Even in the event of a failure, the group key provides more security. (Cho et al, 2008) suggested a "region-based protocol" that divides groups into sub-groups and determines the best method to improve network performance. Using trade, this strategy decreases network traffic overhead between inter-regional and intra-regional overheads" When compared to region-based protocols, non-region-based

protocols perform poorly. Furthermore, (Cho and Chen, 2008) proposed a "region-based approach combined with an intrusion detection algorithm that effectively removes threats." This method selects the nodes with the greatest number of votes in a given region." "It's then loaded with an intrusion detection algorithm that diagnoses the other nodes in the vicinity." As a result, in an application-specific system, it provides a trade-off between security and greater performance." No fixed infrastructure, frequent node failures, connection failures, and a dynamic topology are all features of a mobile ad hoc network. "An method that avoids centralised solutions for these features by arranging the networks in the form of clusters," (Drira et al, 2011) proposed. Better authentication is provided by a trust-oriented cluster approach, which aids in the distribution of node mobility." Even if they are approved, malicious nodes are eliminated via a multicast trust-based method.

Because group keys in routing protocols must be energy efficient, using a distributed key is the best option. "A secure optimized link state routing protocol that distributes efficiently the group keys and controls them well," (Fernandes and Duarte, 2011) proposed. Non-authorized users are prevented from entering the network, and events such as node joining and merging are properly managed." "The strategy effectively minimises control messages while consuming energy throughout the cryptography process." Aside from that, (Veltri et al, 2013) presented a "centralised strategy in the Internet of Things (IoTs) environment for group membership events such as node departing and node joining." This method employs pre-determined time for node joining and unpredictably long time for membership revocation."

(Doh et al, 2013) presented a "code updating system that increases the security and authentication of users during the update process and the creation of group keys." A rekeying mechanism has also been introduced to increase the security and energy efficiency of the virtual backbone medium." "The use of a group controller (GC) in GKMP is implemented for a specific group using HS theory. A single member of the group is represented by a point in HS, and the central point is used as a shared group key." In terms of pseudo-random function, this strategy has been shown to be effective (PRF). Over identity cryptosystems, (Tang et al, 2014) and (Zhang et al, 2015) suggested a "group key agreement technique employing k-bilinear Diffie–

Hellman (DH) exponent." In this case, a single rounded asymmetric dynamic GKMP is used to establish a public key with a variety of decryption keys over group members." " This gives you everything you need.

"Implemented a cross-domain GKMP for patient authentication and used a key generation centre to authenticate patients using a partial secret key." Yang et al. (Yang et al., 2017). "The cross domain incorporates multiple medical institutions using a time-controlled revocation approach that revokes the key when the key expires," says the researcher. (Sepulveda and colleagues, 2017) "To improve the security pattern in hierarchical No C-based group communication, we used two tree-based group-key management." "A member in a specific zone discovers the group key in its own key pool, and the key is discovered using an iterative DH approach," says the author. To compute the key and distribute it throughout the zones, a local manager is used. (2017, Chen and Tzeng) Covers "the issue of group key updates among members and the usage of rekeying mechanisms." A hash function based on XOR is also employed to minimise computation costs." (Bilal and Kang, 2017) suggest a similar "rekeying approach in dynamic group" "with the help of fuzzy trust clustering and hierarchical GKMP to increase the privacy of group members." "Avoided the recurrent refreshing of group key and rekeying in clusters utilising integrated fuzzy trust clustering and hierarchical distributed GKMP in MANETs," according to (Gomathi et al, 2017). "This isolates malignant nodes during data transfer and uses fuzzy logic principles to further identify malicious and trusted nodes." "Proposed area based multiple GKM in VANETs to allow multicast services with decreased communication overhead," (Zhong et al. 2017). It may be deduced from these GKMP methodologies that GKMP with associated modifications based on the network structure gives superior outcomes."

Statement of the Problem

"In non-network environments, where data sharing occurs within closed groups such as organizations or collaborative projects, ensuring privacy protection presents a critical challenge. The absence of robust group key management mechanisms leaves sensitive information vulnerable to unauthorized access, insider threats, and data

breaches. Existing solutions designed for networked environments may not be suitable due to unique characteristics of non-network settings, necessitating specialized approaches. Key issues include the lack of efficient distribution methods for group keys, challenges in implementing effective revocation and renewal processes, scalability concerns, and the need for compatibility across diverse platforms and devices. Without adequate measures in place, individuals or entities within the group can compromise the confidentiality and integrity of shared data, leading to significant financial and reputational risks. To address these challenges, an analytical study is needed to assess the efficacy of existing group key management techniques in preserving privacy within non-network environments.

Need of the study

The need for the proposed analytical study on privacy protection through group key management in non-network environments arises from several key factors:

- Increasing Data Sensitivity: With the proliferation of digital data, organizations and individuals are increasingly concerned about the privacy and security of sensitive information. In non-network environments, where data is shared within closed groups, the need for robust privacy protection mechanisms becomes paramount.
- Limited Applicability of Existing Solutions: Current group key management solutions are primarily designed for networked environments and may not directly address the unique challenges of non-network settings. There is a need to evaluate the effectiveness of these solutions in closed-group scenarios and identify areas for improvement.
- Rising Threat Landscape: The evolving threat landscape, including insider threats and sophisticated cyberattacks, underscores the importance of implementing strong security measures. Inadequate group key management can leave sensitive data vulnerable to unauthorized access, data breaches, and other malicious activities.

Objective of the Study

The main goal of this study is to develop a security protocol for multicast environments in order to protect group (or multicast) communication in wireless networks. The following are the primary research goals:

- To come up with ideas for how to make identification, changing membership, and rekeying work more efficiently in the cloud.
- To make a useful way to protect users' privacy, like using a digital signature and the R-CP method to encrypt data saved in the cloud.
- To see how productive the suggested design is compared to other designs in terms of how well it authenticates, how quickly it changes membership, and how much storage and communication it needs.

Research Gap

The research gap in the context of privacy protection through group key management in non-network environments can be defined as follows: Despite the significant attention given to cyber security and data privacy in both academic research and industry practices, there remains a noticeable gap in addressing the specific challenges related to group key management in non-network environments. This gap is characterized by:

- Limited Focus on Non-Network Environments: Existing research predominantly concentrates on networked environments, such as internet-based communication and cloud computing, neglecting the unique requirements and constraints of closed-group settings where traditional network infrastructure may not be present or accessible.
- Scarcity of Tailored Solutions: While various group key management solutions have been proposed and implemented for networked environments, there is a lack of comprehensive methodologies specifically designed to address the complexities of non-network scenarios. As a result, organizations and individuals operating in closed-group settings often rely on ad hoc or suboptimal practices for managing group keys, leaving them vulnerable to privacy breaches and security threats.

Research of Methodology

The research methodology for investigating privacy protection through group key management in non-network environments involves a structured approach aimed at addressing the identified research gaps and achieving the study's objectives. The following methodology outlines the steps to be undertaken: The purpose of this thesis is to establish a group key management mechanism (GKMP). We believe that this research will add to our understanding of secure group communications in wireless networks in the cloud:

Research Design:

- Given the multifaceted nature of the research problem, a mixed-methods approach will be adopted. This approach allows for the triangulation of data from multiple sources and perspectives, providing a comprehensive understanding of privacy protection through group key management in non-network environments.
- The research design will include both qualitative and quantitative components to capture the complexity of the phenomenon under investigation. Qualitative methods, such as case studies and interviews, will facilitate in-depth exploration and understanding of key concepts and experiences. Quantitative methods, such as surveys and statistical analysis, will enable the measurement and validation of findings on a larger scale.

Data Collection:

- Conducting semi-structured interviews with key stakeholders, including IT professionals, privacy experts, and organizational leaders, to gather insights into their experiences, challenges, and perspectives regarding group key management and privacy protection in non-network environments.
- Utilizing document analysis to examine relevant organizational policies, guidelines, and best practices related to privacy protection and group key management.

Quantitative Data Collection:

- Designing and distributing surveys to a representative sample of organizations or individuals operating in non-network environments to collect quantitative data on their current practices, challenges, and perceptions regarding group key management and privacy protection.
- Extracting quantitative data from existing datasets or repositories, such as industry reports or government databases, to supplement the primary data collection efforts and provide context for the analysis.

Sample of Research:

- The sample for qualitative data collection will be purposefully selected to ensure diversity and representativeness. This may include organizations from various industries, sizes, and geographic locations, as well as individuals with different roles and expertise related to privacy and security.
- For quantitative data collection, a stratified random sampling technique will be employed to ensure a representative sample of organizations or individuals operating in non-network environments. Stratification may be based on factors such as industry sector, organizational size, or geographical region.

Limitation of the study

1. The study may not comprehensively cover all aspects of privacy protection and group key management in non-network environments due to resource constraints or time limitations. As a result, certain factors or perspectives may not be fully explored or included in the analysis.
2. Despite efforts to ensure a representative sample, the sample selection process may inadvertently introduce bias. For example, certain organizations or individuals may be more likely to participate in the study, leading to skewed or non-representative findings.
3. Findings from the study may not be generalizable to all non-network environments or applicable across different contexts. The specific characteristics and circumstances of the sampled organizations or individuals

may limit the extent to which the results can be extrapolated to broader populations.

Conclusion

The study of Group Key Management protocols from 2019 to 2022 reveals significant advancements in enhancing privacy protection and security in non-network environments. The integration of blockchain technology, the development of lightweight cryptographic schemes, and the adoption of dynamic key management strategies represent key trends that address the evolving challenges of modern networks. Future research should focus on further improving the scalability and efficiency of GKM protocols, exploring new cryptographic techniques, and ensuring robust security in increasingly complex and heterogeneous network environments.

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