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ANONYMIZING NEIGHBOR NODES FOR PRIVACY PROTECTION IN MOBILE OPPORTUNISTIC SOCIAL NETWORKS WITH FINE-GRAINED CONTROL

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Abstract: In mobile opportunistic social networks (MOSNs), mobile devices carried by people communicate with each other directly when they meet for proximity-based MOSN services (e.g., file sharing) without the support of infrastructures. In current methods, when nodes meet, they simply communicate with their real IDs, which leads to privacy and security concerns. Anonymizing real IDs among neighbor nodes solves such concerns. However, this prevents nodes from collecting real ID-based encountering information, which is needed to support MOSN services. Therefore, in this paper, we propose FaceChange that can support both anonymizing real IDs among neighbor nodes and collecting real ID-based encountering information. For node anonymity, two encountering nodes communicate anonymously. Only when the two nodes disconnect with each other, each node forwards an encrypted encountering evidence to the encountered node to enable encountering information collection. A set of novel schemes are designed to ensure the confidentiality and uniqueness of encountering evidences. FaceChange also supports fine grained control over what information is shared with the encountered node based on attribute similarity (i.e., trust), which is calculated without disclosing attributes. Advanced extensions for sharing real IDs between mutually trusted nodes and more efficient encountering evidence collection are also proposed. Extensive analysis and experiments show the effectiveness of Face Change on protecting node privacy and meanwhile supporting the encountering information collection in MOSNs. Implementation on smartphones also demonstrates its energy efficiency.

Keywords: Mobile Opportunistic Social Networks, peer-to-peer, Trust Authority, FaceChange

I. INTRODUCTION

AS A special form of delay tolerant networks (DTNs), mobile opportunistic social networks (MOSNs) have attracted much attention due to the increasing popularity of mobile devices, e.g., smartphones and tablets. In MOSNs, mobile devices carried by people communicate with each other directly without the support of infrastructures when they meet (i.e., within the communication range of each other) opportunistically. Such a communication model can be utilized to support various applications without infrastructures, such as packet routing between mobile nodes, encountering based social community/relationship detection, and distributed file sharing and Question & Answer (Q&A) in a community. In each system, a node is uniquely labeled by an unchanging ID (defined real ID), which is obtained from the trust authority (TA), for the corresponding service. Since those services are built upon node encountering, nodes need to collect real ID based encountering information. For example, nodes need to know whom they have met to identify proximity based social community/relationships. In packet routing, nodes need to collect the encountering information to deduce their future meeting probabilities with others. Then, a packet can always be forwarded to the appropriate forwarder.

In current MOSN applications, nodes can collect real ID based encountering information easily since neighbor nodes communicate with real IDs directly. We define two nodes as neighbor nodes when they are within the communication range of each other. However, when using real IDs directly, the disclosure of node ID to neighbor nodes would create privacy and security concerns. For example, a malicious node can first know the IDs of some central nodes or nodes with specific interests. Then, as shown in Figure 1(a), when neighbor nodes communicate with real IDs, a malicious node can easily identify attack targets from neighbors and launch attacks to degrade the system performance or steal important documents. Further, without protection, malicious nodes can also easily sense the encountering between nodes for attacks.

Consequently, there is a challenge on anonymizing neighbor nodes for privacy protection and meanwhile still supporting encountering information collection in MOSNs. There are rich investigations on protecting node privacy in MOSNs. However, most of related works focus on anonymizing interests and profiles and are not designed for neighbor node anonymity, which is a feature provided in this paper. The work in supports neighbor node anonymity but fails to provide encountering information collection at the same time. Therefore, we propose FaceChange to realize bot aforementioned goals based on a key observation in MOSNs. That is, disconnected nodes cannot communicate with each other directly in MOSNs, which makes attacking disconnected nodes almost impossible. This also means that knowing real IDs after the encountering would not compromise the privacy protection. Thus, the proposed FaceChange keeps node anonymity only during the encountering and postpone the real ID based encountering information collection to a moment after two neighbor nodes disconnect with each other.

Encountering Evidence Relaying Scheme: In this scheme, during the encountering, the recipient node specifies a relay node and encrypts its real ID with the public key of the relay node. It then forwards such information to the creator. Later, after the two nodes separate, the creator routes the encountering evidence to the relay node, which decrypts the ID of the recipient node and further

routes the evidence to the recipient node, thereby delivering the encountering evidence.

Encountering Evidence Generation Scheme: More similar attributes (e.g., affiliation and reputation) between two nodes often denote higher trust between them. Thus, we realize the control on the contents in an encountering evidence based on the attribute similarity. We use the commutative encryption and the solution for "the millionaire's problem" to calculate the attribute similarity blindly in this process, which protects node privacy.

With neighbor anonymity, a node may fail to recognize the destinations of its packets even when meeting them, thereby making it hard to deliver packets. We solve this problem by letting nodes pretend to be a better forwarder for packetsdestined for them to fetch these. As a result, packet routing can be conducted correctly and efficiently in FaceChange. This shows that MOSN services can be supported when FaceChange is adopted.

We further design two advanced extensions to enhance the practicability of FaceChange. The first one enables mutually trusted nodes to disclose real IDs to each other during the encountering, and the second one enhances the routing efficiency of the encountering evidence relaying. In summary, the major contribution of this paper is to propose a novel design that supports both neighbor node anonymity and real ID based encountering information collection in MOSNs. FaceChange prevents two encountering nodes from disclosing the real IDs during the encountering, so malicious nodes cannot identify targets from neighbors for attack. When nodes move away from each other, they rely on the encountering evidence to know the real IDs of nodes they have met to support MOSN services. This is acceptable since in MOSNs, a malicious node cannot communicate with a disconnected node for attacks.

II. RELATED WORK

There are already many social network based MOSN routing algorithms. Those works utilize various social factors such as frequently met friends, co-location records, centrality, transient contacts, and contact-based community to deduce a node's future meeting probabilities with other nodes. Then, packets are always forwarded to the node with a higher ability to meet their destinations. There are also some applications in MOSNs. The work proposes three distributed community detection methods in DTNs. In SMART, each node constructs a social map including frequently met nodes to guide packet routing. The works in and realize peer-to-peer (P2P) file sharing and publish/subscribe overlay in DTNs, respectively. In PeopleNet, questions are first forwarded to matched geographical community and then propagated within the community via P2P connectivity to seek for answers. Neighbor nodes in these algorithms communicate directly to collect encountering information for various services. Then, mobile users may be reluctant to participate in the MOSN services due to privacy concerns. Therefore, it is essential to provide neighbor node anonymity for privacy protection.

Anonymizing node interests or attributes for privacy protection in MOSNs has been studied. The work in uses the solution for "the millionaire's problem" to blindly check whether two nodes have similar interests. PreFiler and the work in adopt attribute-based encryption and/or bilinear pairing to blindly check whether a packet matches the destination's interests and whether a node owns the attributes to hold a packet, respectively. The works in and focus on protecting location privacy of mobile nodes. In STAP, packets for a node are cached in places where it visits frequently. As a result, nodes can fetch packets for them without disclosing their location information. SLPD hides the location of a node from the server by relaying its location-based requests among its social friends. ALAR encrypts different fragments of a message with different keys and forwards them separately to prevent advisories from deducing its location from captured fragments. The work in uses additive homomorphic encryption to obtain the statistics of reported data in sensing systems without deteriorating individual users' privacy. In STAMP, nodes generate location proofs for co-location nodes anonymously to protect their location privacy. The works in provide anonymous profile matching between nodes in MOSNs. Find leverages secure multiparty communication to enable a user to find the best match user with limited information exchange. The work in designs a fine grained profile matching algorithm based on Paillier Cyptosystem. Liang *et al*. further propose a seria of profile matching algorithms with full anonymity. The work in lets each node continually change its pseudonym to protect its privacy in MOSNs. There are also researches on secure and privacypreserving communication between neighboring mobile devices. However, most of these systems rely on infrastructures to set up trust, which does not apply to the pure MOSN scenario without infrastructures. SDD enables neighboring nodes to communicate securely with flexible control over the linkability in an energy efficient and distributed manner. However, it cannot directly support the feature of letting nodes collect real ID based encountering information when nodes are anonymized during the encountering. With SDDR, two encountered nodes will either fail to collect the encountering information (when they are not allowed to recognize each other or one party) or disclose their real IDs (when they are allowed to recognize each other). Though effective on protecting node privacy, those methods fail to investigate how to safely collect real ID based encountering information under neighbor node anonymity, which is the design goal of FaceChange.

III. PROBLEM STATEMENT

3.1 EXISTING MODEL

In current MOSN applications, nodes can collect real ID based encountering information easily since neighbor nodes communicate with real IDs directly. We define two nodes as neighbor nodes when they are within the communication range of each other.

Most of existing system works focus on anonymizing interests and profiles and are not designed for neighbor node anonymity, which is a feature provided in this paper.

The work in existing supports neighbor node anonymity but fails to provide encountering information collection at the same time

3.1.1 Drawbacks

When using real IDs directly, the disclosure of node ID to neighbor nodes would create privacy and security concerns.

A malicious node can easily identify attack targets from neighbors and launch attacks to degrade the system performance or steal important documents.

Without protection, malicious nodes can also easily sense the encountering between nodes for attacks.

Pseudonym cannot achieve

3.2 PROPOSED SYSTEM

We propose FaceChange to realize both aforementioned goals based on a key observation in MOSNs. That is, disconnected nodes cannot communicate with each other directly in MOSNs, which makes attacking disconnected nodes almost impossible. This also means that knowing real IDs after the encountering would not compromise the privacy protection. Thus, the proposed FaceChange keeps node anonymity only during the encountering and postpone the real ID based encountering information collection to a moment after two neighbor nodes disconnect with each other.

The major contribution of this paper is to propose a novel design that supports both neighbor node anonymity and real ID based encountering information collection in MOSNs.

FaceChange prevents two encountering nodes from disclosing the real IDs during the encountering, so malicious nodes cannot

identify targets from neighbors for attack. When nodes move away from each other, they rely on the encountering evidence to know the real IDs of nodes they have met to support MOSN services. This is acceptable since in MOSNs, a malicious node cannot communicate with a disconnected node for attacks.

3.2.1 Advantages Of Proposed System

The recipient node specifies a relay node and encrypts its real ID with the public key of the relay node. It then forwards such information to the creator. Later, after the two nodes separate, the creator routes the encountering evidence to the relay node, which decrypts the ID of the recipient node and further routes the evidence to the recipient node, thereby delivering the encountering evidence.

We realize the control on the contents in an encountering evidence based on the attribute similarity.
Packet routing can be conducted correctly and efficiently in FaceChange. This shows that MOSN services can be supported when FaceChange is adopted.

IV. METHODOLOGY

Network Model

We focus on a mobile opportunistic social network with m human-carried mobile devices, denoted by Ni ($i \in [1,m]$). We assume that the network is large. Otherwise, a node can easily guess the identities of its neighbors. Mobile devices/nodes follow the mobility of people carrying them to move in the network. Each node (i.e., device) has a limited communication range, and two nodes can communicate only when they are within the communication range of each other. Efficient neighbor discovery method that dynamically adjusts the neighbor scanning interval can be adopted to save energy.

We assume a Trust Authority (TA) in the system responsible for some system management functions such as system parameters and certificates distribution and attribute validation (e.g., reputation, affiliation, and ID), both of which can be conducted off-line. This is because without a TA, no trust can be built upon the network to support applications. The TA is a fixed server with both wireless capability and Internet access. Its real ID is always visible for easy access. Nodes can access the TA through two ways: 1) when moving close to the TA and 2) when having access to the Internet through WiFi or LTE. When a node connects to the TA, it can get the updated system information such as the set of legal node IDs.

Each node has a unique real ID in the network, denoted by *NIDi*. The real ID of each node is assigned by the TA with a signature generated by the TA's private key, through which nodes can verify the authenticity of received real IDs. DTN incentive schemes can be adopted to encourage nodes to be cooperative.We assume that nodes are cooperative in FaceChange in this paper, i.e., would follow the proposed FaceChange protocol in the network.

Adversary Model

In this paper, we assume malicious nodes can attack targetnodes only when they find targets from neighbor nodes.This is reasonable since 1) an attacker in MOSNs cannot communicate with the target directly if they are not neighbors, and 2) it is costly to attack every encountered node. This meansthat malicious nodes can steal privacies or launch attacks only after identifying target nodes from neighbor nodes. Thus, in this paper, we focus on preventing real ID leakage during the communication between neighbor nodes, while still supporting encountering information collection.

Cryptographic Techniques

1) Bilinear Pairing: Let G1, G2 and GT be three cyclic groups with the same prime order q, and $P \in$ G1 and $Q \in$ G2 be generators of G1 and G2, respectively. A bilinear pairing is a map e: G1 × G2 → GT satisfying the following properties [18]:

- Bilinearity: $\forall a, b \in Z\ q : e(aP, bQ) = e(P,Q)ab$
- Non-degeneracy: $e(P,Q) \_= 1$
- Computability: e can be computed efficiently

V. RESULT

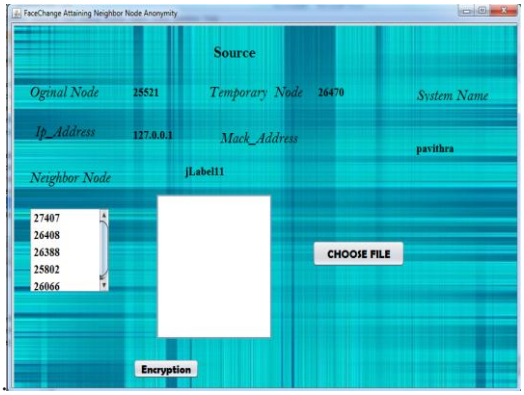

Figure1: Source

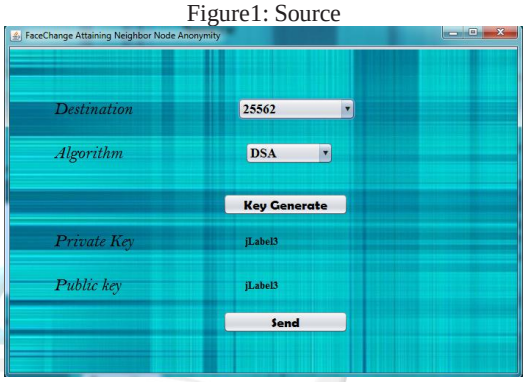

Figure 2: Key Generate

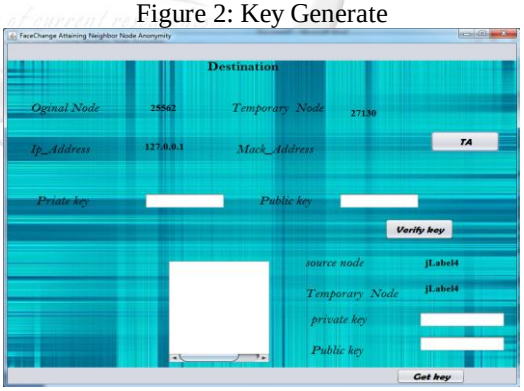

Figure 3: Destination node

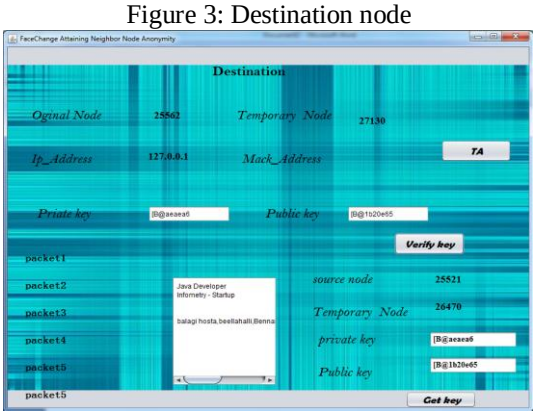

Figure 4: Verified Key and received packets

VI. CONCLUSION

In this paper, a system that supports both neighbor anonymity and real ID based encountering information collection in MOSNs. In FaceChange, each nodecontinually changes its pseudonyms and parameters when communicating with neighbors nodes to hide its real ID. Encountering evidences are then created to enable nodes to collect the real ID based encountering information. After two encountering nodes disconnect, the encountering evidence is relayed to the encountered node through a selected relay node. Practical techniques are adopted in these steps to ensure the security and efficiency of the encountering evidence collection. Trust based control over what information can be included in the encountering evidence is supported in FaceChange. Advanced extensions have also been proposed to support the "white list" feature and enhance the encountering evidence relaying efficiency. Extensive analysis and experiments are conducted to prove the effectiveness and energy efficiency of FaceChange in protecting node privacy and supporting the encountering information collection in MOSNs.

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