An Adaptive Lossly Quantization Technique for Key Extraction Applied in Vehicular Communication

Ibraheem Abdelazeem1 · Weibin Zhang1 · Zhenping Zeng1 · M. S Abdeldime2

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Abstract
Security in vehicular ad hoc network (VANET) is one of the major challenging topics and the secure key interchange between two legitimate vehicles is an important issue. The multi-environment of VANET has been exploited to extract the secret key and employed security services in VANET. However, it offered more excellence randomness owed to fading, noise multi-path, and velocity difference. Some of the factors like Bit-rate, complication and memory requests are reduced by using a process known as quantization. This paper proposes a new quantization method to extract the secret key for vehicular communications that uses a lossy quantizer in combination with information reconciliation and privacy amplification. Our work focuses on the quantization phase for the secret generation procedure. The comprehensive simulations display the propose method increases the zone and number of the quantization levels to utilize the maximum number of measurements to reduce reasonably the wasted measurements.

Keywords Vehicular ad hoc networks · Key extraction · Mobile ad hoc networks · Quantization · RSS

1 Introduction

Vehicular ad hoc network (VANET) is a technology that collects the competencies of new wireless networks with vehicles. It supports various number of applications in the vehicular environment. It is a kind of mobile ad hoc networks (MANETs) that uses vehicles as
nodes. The key difference is that the mobile routers that structure the network are cars [1]. Recently, VANETs have developed and became very popular, because it has a great role in improving road safety, which is one of its most important goals, therefore, it has a significant impact on decreasing accidents and traffic congestions. Besides, it supports a wide range of applications, such as providing traffic management with real-time data for responding to road congestions [2]. Another advantage of VANET can find a better path to access real-time data by saving fuel and time and has wonderful economic and safety benefits. Nevertheless, road safety is the primary goal of these networks [3]. VANET contains three main components namely, trusted authority, constant roadside unit (RSU), and on-board units (OBU) equipped on the moving vehicles. The vehicles are linked to each other (V2V) or with the Road Side Unit (V2R) by single hop or multiple protocols over the vehicle network of the contract [4].

Since accessing the medium in VANET is open, it is vulnerable to many attacks. However, security is an important requirement in VANET. To protection VANET parts from attacks, many solutions have been proposed to afford security requirements against security attacks in VANETs [5]. However, secret key distribution and the basic establishment between legitimate vehicles are the most significant part for all of them, and they are a common requirement and challenge to giving secure communication between vehicles [6–8]. Most of those solutions rely on cryptography and hash functions as a security technicality. Typically, asymmetric key cryptosystems, such as (Diffie-Hellman and RSA) are the most famous techniques for sharing a secret key in many communication systems. Owing to the problem of key distribution between the legitimate parties which face the hash functions and cryptography, particularly symmetric key cryptosystems, although it is the faster and reliable one between all cryptography systems [9]. Meanwhile one of the weaknesses of asymmetric key cryptosystems is spent on a great measure of computing resources, bandwidth, and capacity, which may be obtainable in many scenarios of VANET. Therefore, many researchers have supported to improve other methods, Jian-Yong Hu et al. [10]. Introduced the security proof of the two-way quantum secure immediate correspondence protocol when the noisy and lossy channel may be made under record. In this study the authors improved two-way protocol, previously of encoding the secret message for qubits, Alice firstly executes information compression, and the FEC code will be utilized for encoding. Quantum cryptography is one of these efforts that utilize the quantum concept rules for sharing a secret key. It has been attracted in numerous applications, but it is still in early stages and very costly [11].

The employment of the physical randomness inherent in mutual wireless communication channels is the next stage of the development for secret-key distribution. When using the physical layer (PHY) for secret key extraction, there are important properties of a radio signal that must be considered, which are: (the exchange of radio wave propagation, the chronological differences of the radio channel and the place alternatives). There is strong relationship between quantization schemes and the channel characteristics, used as sources of randomness for secret keys generation [12]. The most general channel factors used to estimate are received signal strength (RSS), channel impulse response (CIR) and phase.

RSS is the most common method because its value is obtainable in all out-of-the-shelf transceivers on a frame basis; therefore, reducing design and implementation costs. RSS values are linked with space, and the entropy is significantly affected [13]. By the movement of the nodes and middle entities, revealing sensitiveness against prognostic and active attacks [14, 15]. One of the most difficult aspects of symmetric key encryption is the key exchange problem. It is critical for the cars to construct a secret key and then deliver it to its counterpart. If the key is stolen or copied before being sent to either entity, a third party could decrypt any cipher-texts encrypted with that key. Recent research has focused on determining a key factor
for remote channels, approved indicator quality (RSS), and retrieving transmitted secret bits between two genuine pairs. It must be demonstrated that these RSS-based solutions can be used on existing platforms. However, they suffer from a variety of difficulties, such as low enter key bit creation and flexibility issues. Authors in [16], exhibited the steps required to extricate those secret key starting with those evaluated normal source from claiming randomness. They exhibited the measurements used to assess the quality of the entered. What is more mulled over the execution about exploiting diverse as a relatable point wellsprings from claiming arbitrariness through bit mismatch rate recreation. By exhibited a qualitative examination between them. In [17], the authors concentrated on those channel testing rate impact on the secret key rate for separate Doppler shifts. They discovered that the secret key rate expands as the testing rate expands and saturates during 20 kHz testing rate to those most exceedingly bad the event Doppler shift they expected from claiming 100 Hz. Another key generation mechanism utilized random probing signals and channel randomness has been presented in [18]. The security excellence of this suggested key generation scheme and the conventional particular case used steady probing signals are investigated and compared under both latent what is more different animated attacks. Unfortunately they are not yet useful to incorporate other physical or physiological data to establish shared secret keys.

We rely on the strengths of the technique of the present techniques suited for VANET that uses a lossy quantize in combination with information reconciliation and privacy amplification to design a secret key extraction strategy suitable for VANET. In order to achieve fully adaptive to the reading the proposed quantization technique changes the position of quantization levels following the readings values, and the proposed method is use $N$ and the readings and simple statistical approach to determine the position of $q_1, q_2, q_3$ and $q_4$. This technique is different from that used in previous work [6]. The proposed work uses the readings itself to adapt the quantization levels, while others use settings value ($u_1, u_2$), which is very hard to be determined and add a complexity issue to the implementation. Efforts and contributions of this work are listed as follows.

- In this paper, we used received signal strength to exploit the wireless channel’s inherent unpredictability to provide secrecy for the key interchange mechanism.
- The quantization levels in our approach will be based on the typical dispersion of estimation readings, and the fine conformity at every two levels will decrease those amounts for drop readings, while those normal RSS values will be removed from the RSS measured because it has the potential to be a predictable work in terms of space.
- As a countermeasure to active attacks, a novel key generation system based on random probing signals and mixing user produced randomness and channel randomness is implemented. According to the simulation results, the proposed approach has a higher security strength.

The rest of the paper is organized as following. Section 2 presents the secret key extraction approach. Section 3 presents the secret key extraction steps. Section 4 displays the simulation results and evaluation. Section 5 concludes the paper.

## 2 The Secret Key Extraction Approach

We suppose that vehicles have a wireless channel to exchange messages, and they can register the RSS readings of the replaced messages. The two vehicles exchange some messages over the wireless channel and register the RSS readings of each message in order to
extract a shared secret key between them. The third side cannot discover any information about the key. We reflect the passive attack sample, where the adversary knows about the method. The legitimate vehicles amount the differences of the wireless channel by transferring sensors to each other and computing the analytical RSS values to find a shared secret key. For identical readings, legitimate vehicles should perfectly amount RSS values at the same time [19–21]. While standard commercial wireless transceivers have one orientation and cannot send and receive signals at the same time, they should measure the radio channel in one orientation at a time. However, as long as the time between two directional channel measurements is very short compared to the channel cohesion rate, we will get identical RSS estimates. The proposed method applied to extract the secret key between legitimate vehicles contains three main stages, as shown in Fig. 1.

3 Key Extraction Stages

3.1 Quantization

Quantization is the process of determining a separate value from an area with potential values for each derived sample. The number of potential values relies on the number of bits utilized to encode each sample [22, 23]. In general, quantitative measurement is obtained founded on particular thresholds. Various options for thresholds and their number represent substantial variation between these quantities. Ordinarily, quantization methods are classified into two main classes which are namely: the lossless and lossy (scalar quantization and vector quantization). The previous generates a great rate production bit current though it does not drop any bits. Nevertheless, employ privacy amplification to raise the uncertainty related by the bits [24, 25].

As several packets are exchanged between two legitimate vehicles, each of them gathers a time sequence of measured RSS. Then, each node quantizes its time series to generate an initial secret bit sequence. The proposed quantize takings of the RSS measurements and

Fig. 1 The main stages of the extract secret key between legitimate vehicles
regulates them into block of size \( N_P \) and computes thresholds. One of the legitimate vehicles starts the key extraction procedure. The sender saves indexed transmission probes to the receiver vehicle, which directly responds to receiving through acknowledgments (ACKs). The probes and ACKs are made as short as possible to be exchanged within the coherence time since this will decrease the Information Reconciliation load [26]. Legitimate vehicles reflect the block of serial measurements of the size \( N_P \). The volume of \( N_P \) depends on the wanted key size. The RSS reading of received packets and their indexes are register by both sender and receiver.

Currently, quantization approaches utilizing a higher and a lower threshold drop on all the patterns which lay among these thresholds [27]. There are a lot of RSS reading information that has been dropped, as shown on Fig. 2. These dropped patterns are damage of useful information that can be applied by legitimate vehicles to create secret bits and also product in passive employment and depletion of resources the wireless channel because additional probes are required to be replaced.

We assume the distance between two vehicles initiator and responder (I,R) is \( D_{IR} \), the distance between Initiator and adversary (I,E) is \( D_{IE} \), and the distance between responder and adversary(R,E) is \( D_{RE} \) as depicted in Fig. 3, and that the recorded reading of (I, R, E) are respectively represented by

\[
D_I = [a_1, a_2, a_3, \ldots a_{N_P}] \\
D_R = [a_1, a_2, a_3, \ldots a_{N_P}] \\
D_E = [a_1, a_2, a_3, \ldots a_{N_P}]
\]

The measurements collected by content the condition of Eq.4 for probes transfer by \( P \) during coherence time \( C_T \).

\[
r_a \left[ \neq r_e, \text{if} D_{AE} > p, D_{BE} > p \right]
\]

Fig. 2 Two quantization levels using higher and lower threshold drops
Thus, one obtains

\[ \mu = \frac{1}{N_P} \sum_{j=1}^{N_P} D_I \]  

(5)

where \( \mu \) is the average of the random RSS readings, \( N_P \) is the number of probes, while \( D_I \) is the set of RSS readings from the initiator side (I).

\[ q_1 = \frac{1}{2} (\mu + \max(D_I)) \]  

(6)

where \( q_1 \) is the first quantization level, as shown in Fig. 4.

\[ q_4 = \frac{1}{2} (\mu + \min(D_I)) \]  

(7)

The legitimate vehicles generate their initial bit streams by extracting two bits for each RSS dimension, conditional on the level intermission in which the RSS dimension leaves and rendering to the quantization rules explained in Table 1. The purpose is to extract a key without a large number of drop information, in additional high entropy, high bit rate, and sensible randomness. Due to the coherence time being too short, the goal is to reduce the lasted measurements as possible to use the most number of measurements. To realize this, we increase the number of samples and adjust the array of quantization levels to adapt to the normal distribution of the readings [5]. Using the above method for finding \( \hat{q}_2, \hat{q}_3 \) values may cause many drops. Therefore, to adjust the levels and reduce the number of drop readings, we use two methods. Firstly, by using level adjustment values \( \alpha_1, \alpha_2 \) for finding \( q_2, q_3 \) as follow:

\[ \hat{q}_2 = \frac{1}{2}(\alpha_1 \mu + q_1) \]  

(8)

\[ \hat{q}_3 = \frac{1}{2}(\alpha_2 \mu + q_4) \]  

(9)

where \( 0 < \alpha_1, \alpha_2 < 1 \).
Secondly, by adjusting the levels using the normal distribution of the readings between $q_1$, $\mu$ and the average of the drops limit as,

\[
\mu_1 = \frac{1}{2}(q_2 + q_3) \tag{10}
\]

\[
\mu_2 = \frac{1}{2}(\hat{q}_2 + \mu_1) \tag{11}
\]

Thus,

\[
q_2 = \text{Rand}[\mu_1, \mu_2] \tag{12}
\]

Similarly,

\[
\mu_3 = \frac{1}{2}(\hat{q}_3 + \mu_1) \tag{13}
\]

\[
q_3 = \text{Rand}[\mu_1, \mu_3] \tag{14}
\]

The quantization levels in our approach will follow the normal distribution of the measurement readings and the fine adjustment of $q_2$ and $q_3$ will decrease the number of drop
readings, while the average RSS value is dropped out of the RSS measured because it can be a predictable function of space, as shown in Fig. 5.

### 3.2 Information Reconciliation

In this stage, after quantization, due to noise and interference, wireless hardware conditions and half-duplex natures of the channel, arise the variances in between bit streams of legitimate vehicles. The information reconciliation technique used to decide upon the same key to proper mismatch bits without any need to exchange some information on the channel that can be utilized by the attacker to detect the extracted secret bits [28]. The existing solutions used for information reconciliation are either error adjustment codes or some communicating information reconciliation procedures. In this study, we applied Cascade [29], which is a two-method information reconciliation protocol. Employing the Cascade approach, one side provides the bitstream randomly, splits it into small blocks and sends variation and consistency information of each block to the other side. While other side offers his bits stream, gaps it into small blocks, computes, and checks if the equality of the blocks correspond or not. For each block whose equality does not correspond, the other side implements a double search to discover whether a small number of bits in the block can be altered to create the block corresponds to the equality information. These stages are repeated many times pending on the chance of attainment becomes upper than a required threshold. The bit streams are missed, and the key extraction method is resumed by measuring new RSS rates. Since the information reconciliation is a probabilistic method, it sometimes may fail [30]. Hence, correct selection to the number of passes and the block size significantly decreases the failure probability.

### 3.3 Privacy Amplification

Privacy amplification is a necessary stage in post-processing, which is used to extract the final secret keys from the identical altered keys between legitimate vehicles [31]. The vehicle needs
to probe the channel just once through its coherence time in order to find independent channel measurements. In VANET, it is very hard to approximation the coherence time of a channel, owing to mobility and the incidence of random movements produced by entities in the environment [32]. Consequently, in the tested RSS data, a bit and the sequential bit are possibly connected since the two consistent RSS measurements happening within the same coherence period. We need another technicality to decrease the connection between subsequent bits, although our quantization method usages dissimilar bit symbol for each interpretation rendering to its position inside the quantization levels, thus that the lastly extracted key from the bit stream is really strong. Privacy amplification alleviates problems that may occur during the information reconciliation stage [33–35]. Such as remove or alteration portions of the bit stream, and an adversary cannot use this information to deduction parts of the extracted key. Moreover, the created bits could have some successive connected bits and have a small entropy rate.

Firstly, in order to raise the randomness and mix of the extracted bits, we use a double arrangement of Markov chain to solve the dependency problem in the quantized bits and to alter the bit stream series. The number of states equal \([s_0, s_1, s_2, s_3]\) by four subs-sequences consistent to a special Markov case, because we have used binary order Markov chain. Every bit in the stream is changed by new bits \((C_{bs})\), which depend on the previous binary bits \((P_{bs})\) in the streaming series and the present value \((C_{bs})\) of the envisioned bit. That is meant by three bits rendering to its present value, and it is previous binary bits, the value of \((N_{bs})\) is envisioned show in Table 2.

Secondly, to find the stable length and low output from lengthier input streams, and to gain a high entropy rate, the legitimate vehicles use a global hash function. Most of the general methods used for privacy amplification are founded on the leftover hash lemma, as a well-known technique to extract randomness from inadequate random sources. Each legitimate vehicles get the last secret key bits of size \((m)\) through calculating the hash value \(h_{P,Q}(x)\), giving to Eq.15.

\[
h_{P,Q}(x) = (P_x + Q) \mod ((P_m \mod m))
\]

### 4 Simulation and Results

#### 4.1 Simulation and Arrangements

There are some assumptions we have to make. Before implementing our Mat lab program, we have to explain the communication environments of two moving vehicles in...
city situations. Initially, we cautious the requirement of IEEE802.11p for communication among vehicles. Then, we utilized a Rayleigh fading channel plus additive Gaussian noise to signify the communication channel conduct. We used dissimilar values of rapidity ranged from 20 to 60 km/h for each vehicle. Utilizing these locations, we sent numerous probes that have randomly created contents plus preambles among the two vehicles, through a rate of 160 probes per second. In the simulation program, we mounted and path the worth of the coherence time. We sent the probes and logged the RSS values using two styles. One during the coherence time and the other after we finished the coherence time.

We reflect measurements for ten tracks over dissimilar molds, making ten datasets, these readings are for the establishment of the secret key, which profits through a few seconds during the transmission process. Additionally, we record these readings along with their consistent mode (drop and useful) and directories to create more analysis on them, in order to evaluate the offered approach and compare it with other alternatives and examine its suitability for vehicular networks. Each of our RSS measurements is quantized to produce one or more bits depending on the quantization scheme and forms the basis for key extraction. We used these datasets as an input to the quantization procedure, for each run of the program. We implement a matlab function to achieve the quantization method rendering to the quantization rules and utilizing the above registered RSS values. It excerpts bits from the un-dropped reading and computes the total of extracted bits as well as the amount of drop RSS reading for each quantization technique. We applied the created bits streams of the two vehicles to evaluate the mismatch bits rate, secret bit rate, and the initial entropy rate. The mismatch rate is the ratio of the number of bits that do not match between legitimate vehicles to the number of bits extracted from RSS quantization, while secret bit rate is the rate number of secret bits extracted per composed measurements.

4.2 Simulation Results and Evaluation

The major issue of the security of the proposed method is those measurements which are composed by legitimate vehicles and the adversary are completely different and random and linked to their locations. We recorded the RSS measurements at three sides within the coherence time of the channel. From the composed reading, we detected that, the measurements at any two sides are nearly similar, while they are significantly different in the third side (adversary vehicle), as shown in Fig. 6. To IEEE 802.11p, the multipath, noise, and distance between two vehicles, as well as the inflection method, greatly effects RSS readings. The impact of quantization level on the amount of dropped RSS values, we noted the number of droops in quantization levels with adjustment. Besides, when we make the normal distribution of the measurement readings and the fine adjustment of the measurement readings and the fine adjustment of $q_2$ and $q_3$ we reduce the number of the drop readings as shown in Fig. 7. Moreover, we entered ten various datasets and quantize them utilizing two, four levels without adjustment with our quantization method. Then we calculated the secret bit rate and drop ratio, as shown in Fig. 8 and Fig. 9. The evaluations of these simulations are plain from those figures that the drop ratio of the proposed quantization outperformed than others, as well as the secret bit rate is very high. The bit mismatch rate (BMR) is an evaluation parameter strictly associated to the quantization step (for example to the number of its levels), and it is defined as the ratio of mismatch bits between the Initiator (I) and the Responder(R) as we mentioned in our model for a secret key generation system in Sect. 3, to the total
number of quantized bits. Low levels of BMR confirm the resilience when we used four quantization levels with adjustment as shown in Fig. 10.

4.3 Metrics Comparison

By using lossy quantization technique provides our scheme security against eavesdroppers. We affirmed this through our simulation performance. Standard randomness tests
demonstrate that our method will be versatile on a meddler exploiting arbitrariness defects. Though, it is worth noting that key rates altogether more amazing over those most extreme doppler recurrence cannot bring about positively irregular probabilities. We explain the scenario and parameters used to perform our simulations and offered as well the simulation results. In terms of simulation results, we present the performance of an adaptive lossy quantization technique for key extraction using different quantization levels as a first step. In the next step to evaluate our performance proposed, we compare the Metrics (secret bit rate, entropy rate and drop ratio) against Abdeldime
M.S [6]. and S. Mathur [17]. The following points show how advanced our method is to these methods.

- Secret bit rate evaluation: Fig. 11 provides the Secret bit rate which is defined as the ratio of average worst-case secrecy rate to total power consumption. As expected, it shows that the proposed robust scheme achieves the highest secure among another compared methods.

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**Fig. 10** Mismatch rate of ten datasets for various quantization levels (2 levels, 4 levels without adjustment, 4 levels with adjustment)

**Fig. 11** Comparison of the secret bit rate
• Entropy rate evaluation: In Fig. 12, the generally used S. Mathur et al. scheme [17], achieves a bit generation rate of approximately 0.4 bits/sample while the recent scheme [6], records 0.86 bits/sample, however, higher results > 0.9 are achievable in our proposed method.

• Drop ratio evaluation: In Fig. 13 we investigate how the drop ratio is the smallest of the three methods when ten samples are taken for testing.

Fig. 12 Comparison of the entropy rate

Fig. 13 Comparison of the drop ratio
5 Conclusion

Vehicular Ad Hoc Networks (VANETs) have great advantages and various goals on the road to raise efficiency and human safety by different applications. All of these advantages will increase security threats and confidentiality problems if security attacks are not completely studied and evaluated. This paper offered a quantization method to extract a secret key by taking advantage of the randomness nature of the wireless channel and to exploit the special properties of VANET. The results that we obtained show that the proposed technique has a high bit rate and entropy rate, besides, the secret bit rate being very high, which reduced the wasted measurements and it can be effectively useful as part of numerous security schemes to offer security services for the VANETs scenarios.

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Ibraheem Abdelazeem  Ms. degree in Nanjing University of Science and Technology, China, in 2020. Currently, he is PhD Student in Nanjing University of Science and Technology. His research interests are intelligent transportation systems and data-driven modeling. Vehicular Ad Hoc Network (VANET).

Weibin Zhang* received Ph.D. degree in automation from Xi’an Jiaotong University, China, in 2008. He worked as a research associate with the Department of Civil and Environmental Engineering, University of Washington, Seattle, WA from 2014 to 2017. Currently, he is a professor in Nanjing University of Science and Technology. His research interests are intelligent transportation systems and data-driven modeling. His current research focuses on application of traffic flow theory, big data in transportation, and machine learning techniques to transportation modeling.