Cooperative Partial Demodulation for Multihop Wireless Communication  

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Abstract— Vehicular Ad hoc NETworks (VANETs) are considered as the backbone of Intelligent Transport System (ITS). They are created for cooperative information exchange. Hence, cooperative communication among vehicles can significantly improve the performance of wireless communication. In this paper, a cooperative scheme named Partial Demodulation of Multi-hop Wireless Communication (PDMWC), which utilizes low-order demodulations to partially demodulate high-order modulated signals cooperatively at intermediate, relay vehicular nodes is proposed. Bit Error Rate (BER) probability is analyzed. The experiment results show that the proposed system significantly improves the performance of multi-hop VANETs with cooperative communication in terms of Packet Delivery Ratio (PDR), Bit Error Rate (BER), Throughput, Energy consumption and Delay.

Key words: Cooperative communication, Multihop wireless communication, Vehicular Ad hoc NETwork (VANET)

I. INTRODUCTION

VANETs are highly mobile. As a result, wireless communication in VANETs suffers heavy signal variations and degradation due to various reasons such as multipath fading [1, 2].

In the recent past, novel opportunistic technologies that offer cooperation among wireless mobile terminals referred to as cooperative relay have been investigated[3-4]. They significantly improve communication. Cooperative communication constitutes a distributed virtual multiple-inputmultiple-output (MIMO) system[5-7]. Cooperative communication is applied to VANET to tackle the problem of high mobility and to improve link quality[9-10]. In wireless communication, normally, high-order modulations lead to increase of BER, particularly under low Signal-to-Noise Ratio (SNR) channel conditions.

Although low order modulations can address the problem, they yield low bit rates. The motivation of this work is to design a cooperative approach that is capable of maintaining bit rates of high order modulations while keeping low error rates of low-order modulations.

The proposed scheme partially demodulates a signal symbol with low-order robust modulations, say Quadrature Phase-Shift Keying (QPSK), at each cooperative relay node. A destination node combines all the partial demodulated outcomes to correctly decode the symbol.

Furthermore, the comparisons of performance between the proposed and conventional schemes are conducted on ns2 simulation tool.

II. RELATED WORKS

Depending on how the information is processed in relaying, various conventional schemes have been proposed in the literature, including Amplitude Forward(AF)[11], Demodulate and Forward(DF) [11-13] and soft DF[14].

In AF, a relay node amplifies the received signals and forwards the scaled signal to the destination. In DF, a relay node demodulates the received signals and forwards the regenerated signals to the destination. In DF, a relay node decodes the received signals and re-encodes and forwards the regenerated signals to the destination. It has been remarked that AF has low complexity and significantly conserves the transmission power.

However, when compared with DF, AF has two main drawbacks. One is that it does not have coding gains, and the other is that it also amplifies and forwards noise. DF has the advantages of regenerating the signal and correcting errors at relay nodes. If the capability of error correction in the decoding is not strong enough to correct all errors, the errors will be propagated throughout the network.

In soft DF, the information in decoding a source signal is used to form a soft signal at the relay based on the log-likelihood ratios. Then, in addition to the raw signal, the signal is transmitted to the destination node using relaying schemes of AF, such as estimate-and-forward and decode-estimate-forward, which use the minimum Mean Square Error (MSE) estimation to optimize the SNR.

Stefanov and Erkip [13] have considered cooperative vehicular application requirements in the design and operation of cooperative vehicular protocols, such as congestion control protocols. They have presented a survey on the classification of various decentralized methods to control the load on the radio channels in a VANET.

Azarian al have investigated the diversity-multiplexing tradeoff of relay protocols [14]. Coding schemes such as distributed turbo codes have been studied to exploit the cooperative diversity for DF in relay channels. Recently, low density parity-check codes were investigated for half-duplex relay channels. If the channel is not reliable enough to guarantee error-free decoded bits at the relay nodes, avoiding error propagation in the relaying becomes challenging. To address this challenge, relay schemes that attempt to combine the benefit of DF and AF were proposed, such as the soft DF protocols [14].

Weixin et al [15] have proposed a differential detection and Orthogonal Frequency-Division Multiplexing(OFDM) cooperative diversity system to bypass the channel estimation and decrease the effect of multipath fading in vehicle to vehicle communications.

III. COALITION FORMATION

In a vehicular network with V2R communications in the service area, the set of Road Side Units (RSUs) is denoted by ‘R’. There are ‘N’ vehicular users communicating with RSUs in this service area.

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To download data from the infotainment server (e.g., video streaming), bandwidth of RSU can be reserved with the cost of $C_t$ per unit of bandwidth per unit of time. The set of RSUs whose bandwidth is reserved by vehicular user ‘i’ is denoted by $R_i \in R$. Vehicular users can form a coalition to share the bandwidth and the cost will be equally divided among them. In the same coalition, vehicular users can access the bandwidth at different RSUs simultaneously. However, if these vehicular users are at the same RSU, the bandwidth will be randomly assigned to one of users with equal probability. User 1 will use the bandwidth, if user 2 is not at RSU1, and vice versa.

However, if both users 1 and 2 are at RSU1, each of them will use the bandwidth with probability 0.5. Users 1 and 2 can reduce the cost of bandwidth reservation at RSU1 by half. However, if users 1 and 2 have high chances to be at the same RSU1, Quality of Service (QoS) may be degraded due to bandwidth sharing. This conflict may be modeled as a coalition game showing the coalition formation among vehicular users. Users form coalition or partitioning through the coordinator.

![Coalition formation among vehicular users](image.png)

IV. COOPERATIVE STEPWISE RELAYING AND COMBINING

The existing cooperative scheme, Cooperative Stepwise Relaying and Combining (CSRC) scheme includes two major topologies of multihop relay system.

The upper topology is a one-branch relay network model; the lower topology is an N-branch cooperative network model. The one-branch model is used to facilitate the explanation of the N-branch system. Both consist of one source, one destination, and distributed relays that cooperatively support the communication between source ‘S’ and destination ‘D’.

In this system, the source encodes information bits and transmits modulated signals to the relay node(s), which demodulates, decodes, and re-encodes the received message. The resulting message is then modulated and forwarded to its successive prospective relay node or the destination node. Finally, the destination receives the signals from the last relay nodes. For the N-branch collaborative communication model, Maximal Ratio Combining (MRC) is assumed as the receive diversity at the destination.

It is assumed that every node in this system can only hear the two nodes next to it. In addition, this relaysystem is an in-band setting, wherein, they transmit and receive over the same frequency band in a half-duplex mode. Its achieved using time-division duplex, where data are transmitted and received in separate time slots.

The relaying channels are quasi-static and independent over time slots. All the receiving nodes have instantaneous Channel State Information (CSI). In order to avoid interference between links, Time Division Multiple Access (TDMA) is used for providing orthogonal channels to facilitate the communications between relays. However, this system fails to support higher order modulations over multihop wireless networks and also lacks QoS while transmitting the signals in multipath channel. As a result, the information sent through the signal gets lost which in turn affects the performance of the communication scheme.

V. PARTIAL DEMODULATION OF MULTIHOP WIRELESS COMMUNICATION

The existing transmission scheme, CSRC used in VANETs have increasing risk of packet loss. This makes the scheme less efficient in terms of security. This paper proposes a scheme named Partial Demodulation of Multihop Wireless Communication (PDMWC) that involves multi-key generation algorithm for secure information transmission. It uses public key cryptosystem as its base.

A. Public-key cryptosystem

In public-key based approach, each message is transmitted along with the digital signature of the message generated using the sender’s private key. Every intermediate forwarder and the final receiver can authenticate the message using the sender’s public key.

The recent progress on the public-key schemes is more advantageous in terms of memory usage, message complexity, and security resilience, since public-key based approaches have a simple and clean key management. Public-key cryptosystem scheme assumes that there is a service whose responsibilities include public-key storage and distribution in the VANETs.

The key assumption here is that the service will never be compromised. However, after deployment, the sensor node may be captured and compromised by the attackers. Once compromised, the information stored in the node will be accessible to the attackers. For efficiency, each public key will have a short identity. The length of the identity is based on the scale of the network.

B. Multi-key Generation

Multi-key generation demands that the acknowledgment packets should be digitally signed before they are sent out and verified until they are accepted. However, extra resources are expended in the generation of digital signatures. To address this issue, partial demodulation is done. The goal is to find the most optimal solution for using digital signature.

Asymmetric key cryptography is used to overcome the key management problem by using different encryption and decryption multiple key pairs. With the knowledge of multiple key (Encryption key), it is not possible to determine the other key (Decryption key). Therefore, the encryption key can be made public, provided the decryption key is held only by the party wishing to receive encrypted messages. Anyone can use the public key and also for any
encrypted message, only the appropriate recipient can decrypt it.

The mathematical relationship between the public/private key pair permits a general rule: any message encrypted with a key for a slot of the pair can be successfully decrypted only with that key’s counterpart. Encryption can be done with the public key, while decryption is feasible using the private key. The converse is also true - encryption with the private key demands decryption only with the public key.

VI. SIMULATION RESULTS
The performance is measured in terms of BER on SNR. The simulations are based on multipath channels in different scenarios. The performance with these channels can be considered as the upper bound. The one-branch model consists of three nodes namely, source, relay and destination, and the two-branch (N = 2) model consists of four nodes namely, source, two relay nodes and a destination.

A. Symmetric One-Branch Channel
In symmetric one-branch channel, the channel conditions of two links are symmetric. The performance is measured from poor to good channel conditions. In BER performance analysis of the PDMWC along the conventional CSRC cooperative strategy, the x-axis refers to the SNR on each link whose simulation result shows the strengths of the proposed strategy in terms of BER.

PDMWC along with the public key encryption outperforms the conventional AF strategy. Specifically, it improves the BER around 2.3 dB over the conventional AF or CSRC strategy. The performance gap between two strategies for 64-QAM is more for 16-QAM, which indicates that the performance gain of PDMWC becomes greater when higher order modulation is employed to achieve a higher data rate. This is because higher order modulation leads to larger errors and gives more space for PDMWC to improve.

B. Asymmetric One-Branch Channel
The SNR of the link between the destination and the relay varies from 0 to 10 dB, but the SNR of the other link is kept constant as low (5 dB is set in experiments). In this scenario, the channel conditions of two links are asymmetric. This scenario particularly evaluates the effect of a low-SNR source-relay condition on the performance. For this scenario, BER vs x-SNR of the link between relay ‘R’ and destination ‘D’ is determined. Unreliable relay links can cause error propagation and highly degrade the performance of cooperative communication.

PDMWC with the public key encryption outperforms the conventional strategy when the SNRs between the relay node and the destination are high. That is because PDMWC decomposes the high-order demodulation into binary demodulation under the cooperation of the relay nodes and avoids decoding errors that significantly degrade the performance of conventional schemes.

C. Symmetric Two-Branch Channel
In a four-node channel model, the lower case is considered, and all the links in the upper and lower branches have the same SNRs, which range from 0 to 10 dB. In this scenario, the channel conditions of two branches are symmetric.

Here, PDMWC employs multi-key generation scheme to combine the signals from the upper and lower branches. This scenario reveals the performance under diversity that is not available in one branch cases. It can be observed that PDMWC greatly outperforms the conventional CSRC, particularly when the order of modulation increases. The reason for this is that the low-order demodulation, i.e., QPSK, is employed at the relay node to ensure that the destination can safely locate the symbol correctly. A high-order demodulation, say 16-QAM is used to detect the remaining part of data. The destination provides diversity gains to compensate the high-order demodulation loss.

D. Asymmetric Two-Branch Channel
The asymmetric links are designed as two branches: All the links of the upper branch have relatively low SNRs (5 dB), but the SNRs of the links in the lower branch vary from 0 to 10 dB. In this scenario, the effect of one low-SNR branch on the performance is revealed. As in the third scenario, PDMWC employs multi-key generation at the destination to exploit the diversity. Although the low-SNR source-relay channels degrade the performance of both PDMWC and AF, it can be observed that PDMWC outperforms CSRC, because the relay nodes use QPSK to demodulate the signals received from the poor-SNR source-relay channels.

VII. PERFORMANCE EVALUATION
The schemes are simulated using ns2. The performance of PDMWC against CSRC and AF is analyzed with varying number of nodes. The simulation parameters are listed below (Table 1).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC</td>
<td>802.11</td>
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<td>Number of Nodes</td>
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<td>Packet size</td>
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<td>Source Position</td>
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<td>Simulation Duration</td>
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<td>Data Rate</td>
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<tr>
<td>Queue Length</td>
<td>50</td>
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</tbody>
</table>

Table 1: Simulation Parameters

A. Packet Delivery Ratio
Packet Delivery Ratio is defined as the ratio of the number of packets received at the destination to the number of packets sent by the source.

B. Bit Error Rate
The bit error rate is the number of bit errors per unit time. The bit error ratio is the number of bit errors divided by the total number of transferred bits during a studied interval of time.

C. Throughput
It is the maximum rate of production or the maximum rate at which packets can be processed.
D. Energy Consumption

It is the energy cost for operating over a network.

E. Delay

Transmission delay is the amount of time required to push all the packet’s bits over the network.

Packet Delivery Ratio (PDR), Bit Error Rate, Throughput, Energy consumption and Delay are the parameters are taken for evaluating the performance of the proposed system.

The following graphs depict the performance of the proposed system.

Figure 2 shows that PDMWC scheme offers better performance in terms of PDR. PDMWC offers 5% better PDR when compared to the conventional CSRC and AF.

From Figure 3, it is evident that PDMWC scheme offers lower Bit Error Rate (BER). PDMWC offers 3.6% less BER when compared to the conventional CSRC and AF.

Figure 4 shows that PDMWC scheme offers better performance in terms of Throughput. PDMWC yields 2% better Throughput when compared to the conventional CSRC and AF.

From Figure 5 and Figure 6, it is evident that PDMWC scheme falls down by 2% in terms of energy consumption and by 4.1% in terms of delay when compared to conventional CSRC and AF.

Hence it is evident that PDMWC offers better performance when compared to conventional CSRC.

VIII. CONCLUSION

Through simulations, the strength of proposed Partial Demodulation of Multihop Wireless Communication (PDMWC) scheme is confirmed with the use of public key cryptosystem which enhances the security in VANETs. The proposed scheme can be further extended to support other higher order modulations such as 256-QAM over multi-hop wireless networks.

REFERENCES


