Ph.D. Research Proposal

Doctoral Program in "Department Name"

Cat Swarm Optimized Resource Allocation and Relay Assisted Message Forwarding under Cellular V2X & D2D Communication Environment

by

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<Date of Submission (DD MM 20YY>

I. INTRODUCTION / BACKGROUND

In recent years, cellular mobile communication networks have dramatically grown over the world that causes a tremendous increase in data traffic. With this spectacular data traffic, wireless cellular network has increased complexity highly. Cellular Vehicle to Everything (C-V2X) is an evolving technology for communication between vehicle to infrastructure, vehicle to pedestrian and vehicle to vehicle that in turn improves the traffic efficiency, road safety and infotainment services [3] [6] [7] [9]. Vehicle to Vehicle (V2V) communication supports exchange of broadcast messages among vehicles. V2V communication is significant in relaying system in regard to transmit message among vehicles [2]. V2V routing in VANET is performed through Autoregressive Integrated Moving Average Model which is composed of four parts that are periodic Hello packet exchange mechanism, candidate relay list update, communication link quality evaluation and candidate relay list selection [4]. Optimization algorithm based routing is proposed in VANET for city environment which is Ant Colony Optimization (ACO) algorithm. Herein, each vehicle generates ant packets to know the information of route between source and destination [5]. Carry and Forward (CF) strategy is used for routing in VANET. CF strategy considers delay constraints for effective routing [8].

Device to Device (D2D) communication is established for V2V communication in VANET. In this, D2D communication is established with the direct discovery and direct communication [1]. D2D communication in heterogeneous network is established with the coalitional games. Herein, resources are allocated to the d2d pairs based on the constructed coalitional game [10]. Two stage relay selection and resource allocation is performed through throughput balance scheme in relay assisted D2D system. Herein, first stage determines the range of candidate relay user equipment through an area division method. In second stage, optimum relay user equipment is selected from the candidate relay [11]. QoE driven resource allocation is performed with the D2D 5G cellular networks. Introduced framework contributions are split into three that are priority based video transmission, flexible communication mode switching of user equipment and subset based relay assignment [12]. . A time division based

intra platoon resource allocation mechanism is proposed where resources are allocated to the d2d users effectually in order to provide high transmission rate [13] [14]. Intelligent Optimization based resource allocation is performed in cellular networks along with improved harmony search algorithm [15].

1.1   Research Outline & Scope

C-V2X communications are considered a strong alternative for vehicular communication technologies such as V2X. In this environment, obtain high packet transmission rate is the main scope of this work.

1.2   Research Objectives

- To avoid frequent link breaches and attains high data rate
- To adopt high dynamic environment and also handle high scale environment
- To discover better device for resource allocation

II.   RESEARCH GAPS

2.1   Common Problem Statement

This section describes the major problems existed in previous works. Here, D2D communication is established only based on the distance constraints that lead to reduce the quality of the multimedia data. Euclidean distance suffers in high dimensionality of vehicle, since it provides same importance to all area. Frequent resource allocation is required due to improper selection cellular users for resource sharing. In this, link capacity limitation is high that leads to packet loss in D2D communication. Dijkstra's algorithm consumes lots of time during path selection, since it follows blind search. Transmission losses are more while routing packets between source and destination due to absence of mobility oriented metrics (speed) in relay selection.

2.2   Problem Definition

In [16] authors present reliable Quality of Forwarding (QoF) based routing for urban VANET using backbone nodes. Herein, best route is determined using computing QoF and link

reliability metrics. Road Weight Evaluation (RWE) Scheme is proposed to provide quantitative evaluation to the road segment. In this, back bone link established through Intersection Backbone Node and Road Segment Backbone Node (RBN). IBN is selected through consideration of staying time intersection. RBN is selected through inter vehicle distance and link connection time metrics. IBN generates Route Evaluation Packet (REP) to transmit neighbour IBN, in order to determine weight of each segment.

Problems

- Road segment weight packets are generated in each intersection and exchanged with all IBN nodes. If density of the network is increased Communication Overhead (CO) is occurs due to creation of backbone link.
- Transmission losses are more while routing packets between source and destination due to absence of mobility oriented metrics (speed) in relay selection.

Proposed Solutions

- Our proposed method doesn't exchange control packet that in turn reduce communication overhead in the V2X network
- Our proposed Cooperative Game Theory based routing reduces transmission losses effectively using speed and connectivity strength.

In [17] author proposes multi-hop routing to deliver data in the Vehicle to Everything (V2X) network. In this, Vehicle to Vehicle Communication and Vehicle to Infrastructure (V2I) communication is established. Herein, multi-hop routing is performed through Carry and Forward (CF) strategy where V2V communication is established. To determine optimum vehicular pair, Karush Kuhn Tucker (KKT) conditions are used. Proposed KKT taken latency and data rate metrics into account in regard to compute weight. Highest weight vehicle is selected for V2V communication. If any optimum vehicle is not determined within the time, then it request Road Side Unit to discover vehicle for V2V communication.

Problems

- Achieving global convergence rate is complex in KKT condition due to usage of non-smooth formulation.
- Packet losses and time required for transmission are more in carry and forward strategy.

Proposed Solutions

- Our proposed Cooperative Game Theory based routing achieves less packet loss and transmission time with consideration metrics such as speed and connectivity strength.

In this work author proposes [18] mobility aware relay selection in D2D communication using stochastic model. Stochastic Integer Programming (SIP) model is converted into the Mixed Integer Non Linear Programming (MINLP) model. Herein, Connectivity Factor (CF) is computed to made D2D communication among vehicles which is calculated in per hop basis. CF metrics captures node mobility and link reliability metrics. Operator Controlled based D2D communication is performed through Dijkstra's algorithm and Device controlled based D2D communication is performed through Ad-hoc On Demand Vector algorithm.

Problems

- Dijkstra's algorithm consumes lots of time during path selection, since it follows blind search. Capacity limitation of link in the path is high that leads to packet loss in D2D communication. MINLP cannot able to achieve global solution in relay selection due to tedious computation process.

Proposed Solutions

- Our proposed d2d communication utilizes Hybrid Q-SARSA for relay selection which considers Signal to Noise Ratio (SNR), link strength and Chanel State Information (CSI) in order to reduce packet loss.

In this paper author [19] proposes Device to Device (D2D) media services distribution scheme under QoE in cellular networks. Dynamic distributed heterogeneous Media Services Adaptive Update Scheme is proposed for D2D communication. Three types of services are taken such as Best Effort Service (BES), Audio and Video services. D2D media service distribution

scheme is performed based on the priority function and popularity function. Device discovery process utilizes Euclidean distance to select optimum device to establish D2D communication.

Problems

- In this, D2D communication is established only based on the distance constraints that lead to reduce the quality of the multimedia data.
- Euclidean distance suffers in high dimensionality of vehicle, since it provides same importance to all area.

Proposed Solutions

▶ Our proposed d2d communication established with consideration of Signal to Noise Ratio (SNR), link strength and Chanel State Information (CSI) metrics that improves quality of the multimedia data.

This author proposes [20] sector based resource allocation algorithm to achieve better Quality of Service and Experience in D2D communication. Herein, cellular coverage area of the base station is divided into three 120^0 sectors. Each sector is allocated with equal number of users and cellular uses are allocated with equal number of resource block. D2D pair is formed based on the distance constraints. Three types of services are provided in d2d communication that is Non conversational video, conversational video and conversational voice. Resource is allocated to d2d pair based on the application demanded using Hidden Markov Model (HMM). Cellular users selected for resource allocation is based on the channel gain.

Problems

- Frequent resource allocation is required due to improper selection cellular users for resource sharing. HMM based resource allocation is not effective, since it cannot capture correlation between the variables.

Proposed Solutions

- We propose Cat Swarm Optimization algorithm for resource block allocation that allocates optimized resource blocks to the requested d2d pair.

III. RESEARCH CONTRIBUTIONS

Our proposed framework tackles the problems that are present in the existing cellular V2X communication. Our network comprises of *Vehicles, User device in vehicle, Pedestrians (Cellular Users (5G)), and 5G Basestation.* Our proposed work contributions are divided into three fold that are Coalition based routing, D2D communication and SignRank Oriented Pedestrian Selection and Emperor based Resource Allocation.

SYSTEM ARCHITECTURE
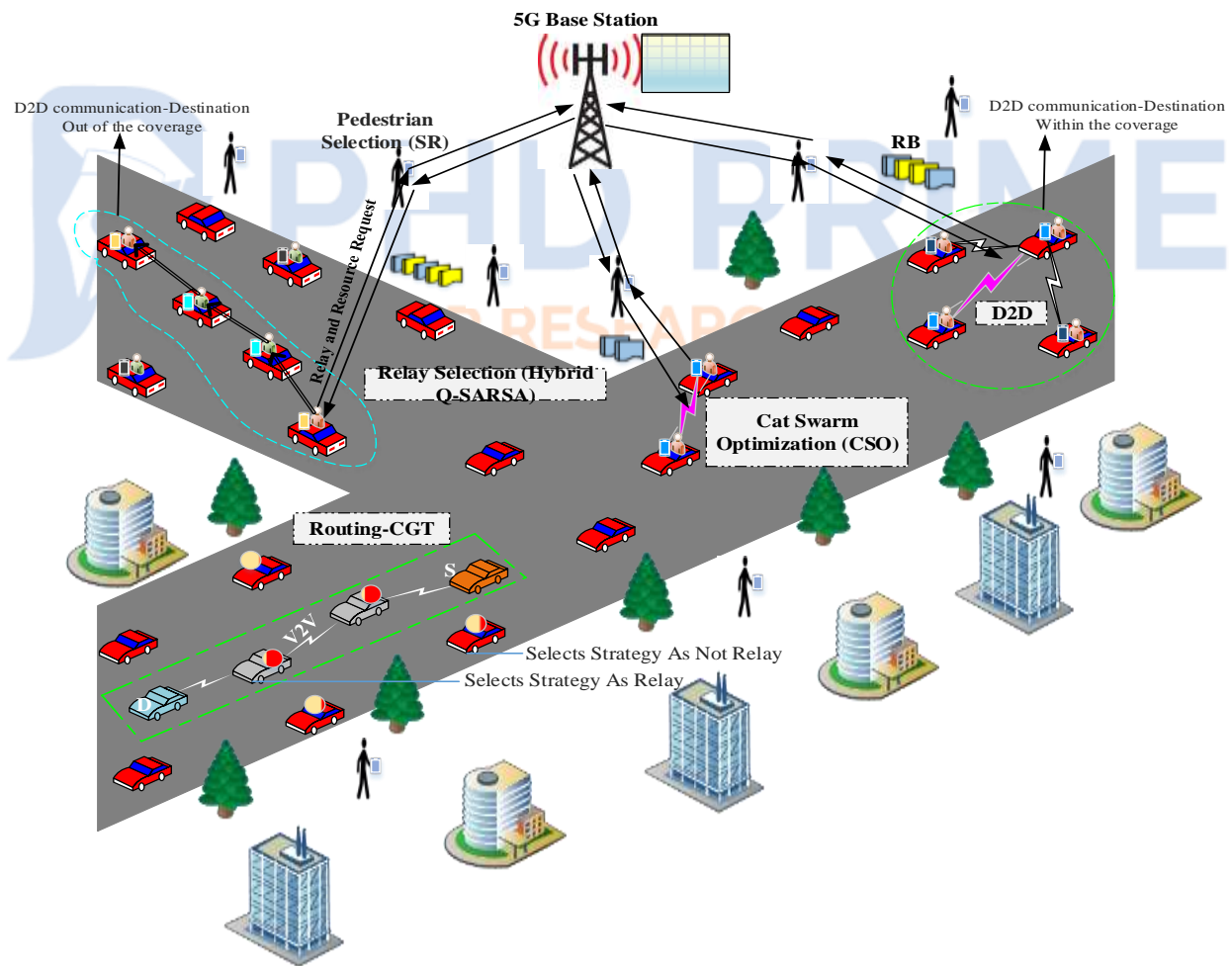
1. Packet Loss Aware Routing

Regarding to reduce transmission time and packet losses during routing, we propose **Cooperative game Theory,** In CGT, vehicles are considered as players and to act as relay, it must select strategy based on the computed utility function. We consider two strategies in our work that are act as forwarder and not act as forwarder. In order to select strategy as forwarder, player must have high utility function. If player select strategy as forwarder, then it forms V2V communication with next forwarder in order to transmit packet to destination. If player get less utility function, it cannot act as forwarder for that coalition. Utility function is computed using metrics such as Quality of Forwarding, Expected Transmission Delay and Connectivity Strength.

2. D2D communication and WASPAS Pedestrian Selection

Our D2D communication is performed in two cases that are: 1) Device discovered within the coverage 2) Device discovered in out of coverage. In first case, destination device discovered within the coverage of discoverie. In second case, destination device discovered in out of the coverage range of discoverie with the aid of pedestrian. In this case, device selects best pedestrian to communicate with basestation in order to discover destination. Pedestrian is selected using **WASPAS** algorithm which taken farness from the basestation, battery level and relative speed into account. Device send relay request to the basestation via selected pedestrian. Basestation implements **Hybrid Q-SARSA** for relay selection in D2D communication where following metrics are considered Signal to Noise Ratio (SNR), link strength and Chanel State Information (CSI).

3. Cat Swarm Optimization based Resource Allocation

D2D pair send resource allocation request to the 5G base station through selected pedestrian. Basestation sends resource blocks to the requested D2D pair through pedestrian. Pedestrian allocates resource blocks using **Cat Swarm Optimization** algorithm which contains behaviour of both swarm and nature inspired. Proposed EPC algorithm allocates optimized resource blocks to each D2D pair based on the subsequent metrics that are Signal to Interference

plus Noise Ratio (SINR), application service and data size. Our proposed work considers two services such as video and audio.

Performance Evaluation

Finally, validates the proposed work performance using following metrics,

- Packet Delivery Ratio (%) w.r.t packets generation speed
- PDR (%) w.r.t number of nodes
- Average Transmission delay w.r.t packets generation speed
- Average Transmission delay w.r.t number of nodes
- Throughput (%) w.r.t number of nodes
- Mean Opinion Score (MOS) w.r.t number of nodes
- Jitter w.r.t number of nodes

IV.   RESEARCH NOVELTIES

- Our proposed Coalitional Game Theory based routing achieves less transmission time with consideration metrics such as speed and connectivity strength while routing packets to the destination.
- Our proposed d2d communication utilizes Hybrid Q-SARSA for relay selection which considers Signal to Noise Ratio (SNR), link strength and Chanel State Information (CSI) in order to reduce packet loss.

V.   PREVIOUS WORKS & LIMITATIONS

Paper 1

Title - Interference Management Strategy for 5G Femto cell Clusters

Concept

In this paper, full scheme of resource management that can be applied in the instances of the Femtocell deployment of increased density. Ultra dense heterogeneous networks seem to be one of the main drivers to answer the need for larger device connectivity and increased data rate. Multiple base stations with different specification will be deployed to achieve these targets. Femtocells are a type of base station that is expected to dominate due to their low cost and easy deployment and maintenance

Paper 2

Title - A Routing Framework for Offloading Traffic from Cellular Networks to SDN-based Multi-HopDevice-to-Device Networks

Concept

In this paper, we propose a new routing framework called Virtual Ad hoc Routing Protocol (VARP).This framework introduces significant advantages such as better security, lower routing overheads, and higher scalability, when compared to conventional ad hoc routing protocols. It also reduces traffic overhead in LTE networks using multi-hopD2D communications under management of a SDN-controller. Further, it enables the development of various types of routing protocols for different networking scenarios. To this end, a source-routing based protocol was developed on top of VARP, referred to as VARP-S.

Paper 3

Title - QoE-Driven Resource Allocation for Live Video Streaming Over D2D-Underlaid 5G Cellular Networks

Concept

This work proposes QoE driven resource allocation for video streaming over d2d underpaid 5G cellular networks. Proposed framework contributions are split into three that are priority based video transmission, flexible communication mode switching of user equipment and subset based relay assignment. Proposed system dynamically adjusts the ratio between d2d and cellular users. Proposed method improves QoS/QoE metric through continuity of playback,

PSNR, quality fluctuation for playback and energy consumption overhead by relay based on the D2D communication.

Paper 4

Title - Resource Allocation Schemes Based on Intelligent Optimization Algorithms for D2D Communications Underlaying Cellular Networks

Concept

This paper proposes resource allocation schemes based on the optimization algorithms for d2d communication underlaying cellular networks. This paper assumes number of device users is larger than the cellular users. Herein, resource blocks are divided into two types that are one for cellular users and another for device users. Resource allocation is based on the genetic optimization algorithm. In order to improve the performance of the resource allocation improved harmony search algorithm is utilized.

Limitations

- Here, Genetic algorithm is used for resource allocation which takes more time in allocation of resources to the d2d pairs.

Paper 5

Title - Resource Allocation for Underlay D2D Communication with Proportional Fairness

Concept

This paper proposes resource allocation for underlay d2d communication with proportional fairness. This work proposes novel joint power control and resource scheduling scheme in regard to enhance the throughput and user fairness of underlay d2d communication networks. Proposed fairness function considers parameters such as fairness, Signal to Interference plus Noise Ratio (SINR) and severe interference for proper resource allocation. Proposed algorithm taken into consideration of longer time slot of duration for resource allocation.

Paper 6

Title - Resource Allocation for D2D-Enabled Communications in Vehicle Platooning

Concept

This work proposes resource allocation for d2d communication in vehicle platooning. Herein, two stage platoon formation algorithm is proposed for platoon leader selection and formation. A time division based intra platoon resource allocation mechanism is proposed where resources are allocated to the d2d users effectually in order to provide high transmission rate. Inter platoon resource allocation is performed for cellular users with minimum transmission rate for each platoon.

Paper 7

Title - A Two - Stages Relay Selection and Resource Allocation with Throughput Balance Scheme in Relay-Assisted D2D System

Concept

This paper proposes two stage relay selection and resource allocation with throughput balance scheme in relay assisted d2d system. Herein, first stage determines the range of candidate relay user equipment through an area division method. In second stage, optimum relay user equipment is selected from the candidate relay. In this, resource allocation is performed through optimal bipartite graph theory with low complexity.

Paper 8

Title - Resource Allocation for Device-to-Device Communications Underlaying Heterogeneous Cellular Networks Using Coalitional Games

Concept

This work proposes resource allocation for device to device communication in underlying heterogeneous cellular networks using coalitional games. Coalitional game theory is used for

resource allocation for D2D communication in cellular networks. Herein, coalitional formation game is proposed to increase the average sun rate in statistical average sense. Nash stable equilibrium is achieved through the proposed coalition game theory. Based on the game theory resource is allocated to the D2D pair.

Paper 9

Title - A Novel Base-Station Selection Strategy for Cellular Vehicle-to-Everything (C-V2X) Communications

Concept

This paper proposes base station selection strategy for cellular vehicle to everything communication. At first, this paper proposes mechanism to predict the received signal strength for base station selection strategy. Herein, Markov Decision policy is proposed for received signal strength selection. In Markov Decision Policy, each vehicle is considered as the competitor for optimum base station selection. Herein, maximum value function for each strategy is obtained for optimum base station selection.

Paper 10

Title - VANET aided D2D Discovery: Delay Analysis and Performance

Concept

In this paper, VANET aided d2d discovery is proposed and analyzes the delay and performance of the proposed work. The proposed algorithm comprises of two phases that are initialization phase and transaction phase. Initialization phase makes the entire surrounding node aware of its position and the transaction phase answers the user request. Herein, clustering is formed based transmission range, if the transmission range of the two node intersects then it forms cluster. Device discovery process is performed whenever OBU receives device discovery request. Carry and Forward strategy is used to deliver the message over the vehicle to the destination.

Limitations

- Carry and Forward strategy based routing takes more time to transmit data packets to the destination that induces packet loss.

Paper 11

Title - Energy Efficient V2X-Enabled Communications in Cellular Networks

Concept

This work proposes energy efficient V2X communication in cellular networks. Relay assisted transmission scheme is proposed for delay sensitive application. Relay selection is based on the delay constraints in order to reduce delay during vehicular communication. Sequential Quasi Convex optimization algorithm is used for relay based transmission scheme. Optimal transmission time is considered for relay selection.

Paper 12

Title - A Novel Low-Latency V2V Resource Allocation Scheme Based on Cellular V2X Communications

Concept

This paper proposes low latency V2V resource allocation scheme based on the cellular V2X communication. For V2V communication, greedy cellular based V2V link selection algorithm is proposed. In this, each vehicle computes its packet lifetime and requests the eNodeB to establish V2V link for communication. Herein, weight is computed weight in V2V communication, we develop an analytical approach. Weight is computed based on the two metrics that are latency and packet delivery ratio.

Paper 13

Title - Traffic-Aware VANET Routing for City Environments— A Protocol Based on Ant Colony Optimization

Concept

In this paper, Ant Colony Optimization (ACO) based VANET routing is performed for city environment. Herein, enhanced version of geographic routing protocol is proposed for route selection. This paper generates ant packets and exchange with other vehicles in order to compute weight for each street which is proportional to the network connectivity. In regard to find the optimum route between source and destination, source vehicle access path map and computes weight, path which has lowest weight is considered as route for packet transmission.

Limitations

- ACO based route selection is proposed which consumes uncertain time to converge into optimal solution.

Paper 14

Title - Vehicle-to-Everything (v2x) Services Supported by LTE-based Systems and 5g

Concept

This author proposes Vehicle to Everything (V2X) services which is supported by the LTE based systems and 5G networks. Herein, five categorizes of service requirement is introduced that are speed, communication range, latency/reliability, message size and message generation period. LTE based D2D communication is performed through two types of mechanism that are mode 1 and mode 2. Herein, mode 1 follows centralized control mechanism and mode 2 follows distributed control mechanism.

Paper 15

Title - RA-eV2V: Relaying Systems for LTE-V2V Communications

Concept

In this paper, Relay Assisted enhanced Vehicle to Vehicle (RA-eV2V) communication is proposed. Herein, Co-operative Awareness Message (CAM) is transmitted between vehicles

through V2V communication. Herein, two modes are considered for V2V communications that are standard mode and Non-standard mode. Standard mode follows the 3GPP standard whereas Non-standard mode follows the modified version of the 3GPP. Road Side Unit (RSU) present in the network is used to relaying message s from the vehicular users.

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