Efficient Path Selection and Throughput Maximization in Device to Device Communication

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***Abstract*- One of the most powerful technologies in the wireless cellular networks is device to device (D2D) communication as it could be employed to improve the energy efficiency, spectral efficiency, data rate, reduces links latency and also improves the network capacity. Now more than ever, optimizing resource allocation and path selection is becoming more critical due to the growth of consumers or devices. Most of the existing research work mainly emphases on both increasing the throughput by consolidating resource blocks and power assigning method. The enormous growth in the number of consumers increases the requirement of large number of spectrum resources to support various applications. Not only this, it also put massive burden on the base station. Very limited number of analysis refuges the option of choosing the finest path and resource allotment in multi jump D2D.So in this paper, we tried to compare different path selection and throughput maximization algorithms. For the path selection Q learning algorithm and Dijikstra algorithm is considered. Second stage deals with implementation of PSO and GSA which is applied for finding the throughput. A comparison has been made between the implementation of PSO and GSA optimization.**

***Index Terms*- D2D communication, Multi hop, Power allocation, Q- learning, GSA, PSO.**

I. INTRODUCTION

Most of the researches are looking for wireless data transfer with great throughput efficiency to meet the demand of the amplified consumers. Recently VNI has predicted that by the end of 2030, the number of global users is likely to extent up to 500 billion. To fulfill the increasing consumers demands the 5th generation communication maintains a lot of different technologies. One of those technologies is device to device communication which can meet the huge demand of exponentially growing traffic. In future, it is expected that more than 80% of communication will be reinforced by D2D links. D2D communication is the communication of two devices with the minimum usage of the base station [2-4]. D2D communication is further classified into two groups. One of them is single hop d2d communication and another one is multi jump d2d communication. Many advantages like refining energy and spectral efficiency through proximity and resource recycle can be achieved with the help of single D2D communication. But, many of the researches show that direct D2D communication is confined with restricted proximities. So fully exploiting the potential of the direct D2D communication is not possible. However, this can be achieved through multi step communication. The communication will be done from source to intermediate and intermediate to target with availability of resource block. Two connections between D2D pairs are at least required for multi hop communication. The resource chunks are allocated by the base station on the basis of channel state index and SINR. The main challenges posed by multi jump D2D communication are relay assortment and distribution of resource. In relay assortment, the base station has an important role. Among the accessible equipment's between d2d pair, the base station decides and chooses the finest potential relay device. Many authors have already proposed relay selection method [1-3]. The base station plays an important role in assigning resource blocks to cellular users for multi hop D2Dcommunication. Multiple Resource allocation strategies have been suggested by different authors. In some cases same resource chunk has been assigned for both steps while in others dissimilar resource chunks are assigned for each jump [4- 11]. A cell area enclosed with a base station where six cellular consumers (C1, C2, C3, C4, C5, C6), with their resources (R1, R2, R3, R4, R5, R6) has been depicted in Figure 1.

II. LITERATURE SURVEY

The reusability of cellular possessions is the reason for much received attention for the multi hop D2D communication. In this type of communication, communication can be done with the aid of equipment's (relay) when the D2D consumers are not in the juxtaposition. This type of communication is known as multi jump d2d communication.

Minimum number of links required for establishment of D2D pair (Source to intermediate and intermediate to target) is two. For multi jump D2D communication both the links required resource blocks. The main advantage of multi jump

D2D communication is it upsurges the proximity area. This results into communication to longer distances with the help of equipment's with minimum contribution of the base station. It also surges the network throughput and spectral efficiency which is achieved by reusing the identical resource chunk of cellular consumers. The important aspect of multi jump D2D communication is relay selection. Proper relay selection is very important as it improves data rate, reduces both data loss and energy consumption for transmission. For selection of relay, number of applications has been projected in different journals. In [19], an energy efficient routing scheme has been proposed which is helpful in expanding the application in D2D multi jump networks. Reduction of hop count which is a kind of intrusion routing procedure has been projected in [18]. This proposed algorithm helps to downcast the delay and power depletion from source to target. To increase operational coverage area of base station for public safety communication has been considered in [2]. In [3], a routing algorithm for maximum throughput between sources to destination D2D pair has been considered with interference constraints which are imposed by the cellular network. In most of the path finding studies, future state based on the current state are calculated. In this paper, we have tried to find out efficient path based on Q learning route finding method.

In most researches, resource distribution for D2D consumers has been done by allocating resource to a single D2D consumer. In the paper [25], the authors have tried to implement Max Mean Far distance technique which will provide resources to all consumers in the relay route. Resource allocation poses two major challenges in case of multi hop D2D communication. The first challenge is the interference caused by D2D devices to cellular users. It can critically affect the performance of the cellular users. The other challenge is the requirements of better QOS for D2D communication. Many authors tried to minimize interference for direct and multi hop D2D in case of resource sharing. Many methods have been projected for resource allocation which is characterized as graph theory, optimization theory and game theory. In [4], author has considered a downlink scenario in which resource allocation has been done considering particle swarm optimization technique. User have the freedom to alter their mode either cellular or D2D mode user depending upon the proximity. The assumption is that the CSI has been calculated by the base station and sent for all the users. In [5], PSO algorithm is used to deal with network power distribution issues in D2D cellular network. The main objective [5] is to decrease interference and improve the system performance. The PSO based resource allocation has been proposed in [6], which is used in achieving maximum throughput [6]. The authors have considered the aloofness between the base station and the cellular user as the cost function parameter for the investigation. The authors have explored to increase the throughput thoroughly by applying optimization. But the optimization takes a long time to achieve maximum throughput. It has been concluded that basis optimization plans explore or exploit users. In this paper, we have considered two algorithms that are PSO and GSA optimization technique which has less time complexity and minimum iteration to achieve the maximum throughput. An energy conscious heuristic graph based approach has been taken into consideration in [7]. It can solve both routing and resource allocation for side link interference and multi hop path. The method is named as JRRAEE. In [8], a scheme for multi hop D2D communication is planned to improve the end to end connection among devices which are in proximity area. A graph based resource distribution method has been defined which is used to fulfill the bandwidth requirements for all the relay devices.

A. Motivation

Time complexity is at most important for choice making and finding the finest path which is possible. Many authors proposed path finding algorithm for multi-step D2D path. But the chief matter with these procedures is that they pick the subsequent node considering the preceding knot. Hence, these technique increases the time complexity for discovering the unsurpassed probable path. In this paper we tried to discuss about Q learning centered rout finding method which would assist to pacify the absence of judgment making for path assortment. Here, the overall reward function has been calculated from the source node to the target node. Additionally, the multi jump D2D has to deal with problems like inefficient and unsuitable resource management for the user on the relay path. In paper [21] a Max Mean Far distance (MMF) algorithm which is intended on the basis of considering present and next node for the path selection. In this algorithm, cellular users are identified that can share the resource to all nodes without any interference in the complete path. In many journals, PSO and GWO algorithms are recommended for solving the miscellaneous integer programming experiment to augment system throughput. PSO process has the capability to discover while GWO algorithm has the power to exploit. In this paper, we will try to show the comparison among PSO and GSA.

B. Key contribution

The contribution of the papers is as follow:-

1. The paper deals with the problem of eminence path assortment for multi jump D2D communication. We tried to finding the best path using Q- learning algorithm.

2. Simulations are carried out to authenticate the methods. We tried to figure out an assessment between the dissimilar algorithms. The simulation result shows the enactment of these systems.

III. SYSTEM MODEL

In this paper, we have considered D2D communiqué that uses the uplink resource range of cellular users. The base station is placed at the cell center and random distributed cellular user (C) surrounds the base station. The set for cellular user is defined as C_m where m= 1,2, 3, ……j…..N . Let us suppose K denotes the number of resource block K =1, 2,… K. D2D pairs necessarily employs the multi hop relay path between them so as data can communicate from source to target. We have considered the number of potential nodes in the multi jump path is given as Mmh where mh =1, 2, .., MH. Choosing a relay between source and target and routing the data through it, helps to maximize the worth of communication amongst the D2D pairs and increases the resource throughput. The base station acts as an authority band it receives the appealed message which is the relay request transmitted by D2D transmitter. D2D transmitter must meet the minimum data transmission rate dr_{min} that is $dr_d > dr_{min}$. If the above condition is fulfilled then only the relay contributions to the D2D knots for their message delivery. The communication between the source and the target in D2D communication recycles the resource chunk of a solo cellular consumer. Figure 2 depicts the multi hop D2D relay communication underlying cellular communication. In Figure 2, we have considered C_6 cellular user as the source node which will transmit the data through the relay path in D2D mode to the target cellular userC_1. C_2 act as the intermediate node between C_6 and C_1. In the first time period, C_6 as the starting node D_6 communicates. The data to C_2 as intermediary node D_2 in D2D mode by involving the resource chunk R5 of the cellular consumerC_5. In the second time period, D_2 which is the intermediary node and behaves as the spreader and it forwards the data to its target which is the node D_1 by involving the identical resource chunk R5. In first time period D_6-D_2 communicate as D2D duo and in the second period D_2-D_1 communicate in D2D mode.

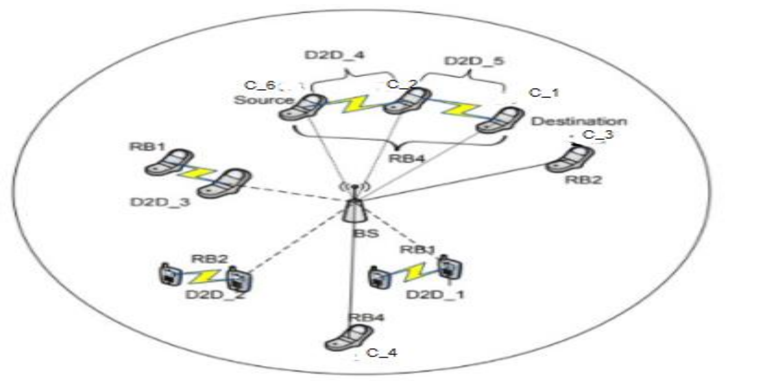


Figure1: System model of multi hop relay D2D communication

IV. NETWORK MODEL

Here we have considered that all the D2D users are casually spread over the cell zone. The signal to noise ratio at the base station of reception signal from C_i with k^{th} resource block is given by

$$\delta_{C_i-eNB} = \frac{P_{C_i-eNB}\,(d_{C_i-eNB})^{-\alpha}}{\sum_{j=1} P_{DjTX}\,(d_{C_i-eNB})^{-\alpha}\,(p_{ij}) + N} \quad (1)$$

Throughput of Shannon bulk model for cellular communication with bandwidth B is considered as

$$dr_{C_i} = B\log_2(1+\delta_{C_i-eNB}) \quad (2)$$

Similarly,

$$\delta_{DjTX} = \frac{P_{DjTX}\,(d_{DjTX-eNB})^{-\alpha}}{\sum_{j=1} P_{C_i}\,(d_{C_i-DjTX})^{-\alpha}\,(p_{ij}) + \sum_{l=1} P_{DlTX}\,(d_{DlTX-DjTX})^{-\alpha}\,(p_{lj})} \quad (3)$$

Where the power of cellular consumer and power of D2D spreader is given as P_{C_i}, P_{DlTX}. According to the Shannon capacity model the throughput for D2D user is given as

$$dr_{D_{jTX}} = B\log_2(1+\delta_{DjTX}) \quad (4)$$

Resource chunks reuse with D2D pairs roots inter channel intervention. The intervention of the cellular consumer is calculated as

$$I_m = \sum_{m=1}^{N} P_{DjTX} * g_{DjTX-C_m} \quad (5)$$

Here, P_{DjTX} represent the D2D transmission power and g_{DjTX-C_m} represents the gain concerning D2D pair and the cellular consumer.

The intrusion at the base station is calculated as

$$I_{eNB} = \sum_{m=1}^{N} P_{DjTX} * g_{DjTX-eNB} \quad (6)$$

Where $g_{DjTX-eNB}$ denotes gain of D2D pair to base station.

The intervention between the D2D transmitter and receiver is calculated as

$$I_n = \sum_{m=1}^{M} P_{DjTX} * g_{DjTX-DjRX} \quad (7)$$

The overall intervention caused in the arrangement is given as

$$I_T = I_n + I_m + I_{eNB} \quad (8)$$

The multi jump relay spreader side, SINR is given as

$$\delta_{MTX} = \frac{P_{DjTX} * g_{DjTX,m}}{\sigma + I_T} \quad (9)$$

The relay receiver side SINR with the kth block is given as

$$\delta_{MRX} = \frac{P_{DjRX} * g_{DjRX,m}}{\sigma + I_T} \quad (10)$$

The minimum of SINR of the hops is considered as the end to end SINR and it is given as

$$\delta_{s\_r} = \{\delta_{MTX}, \delta_{MRX}\} \quad (11)$$

The relay throughput can be expressed as

$$dr_m = B \log_2(1 + \delta_{s\_r}) \quad (12)$$

The throughput for the system is given as

$$DR = \sum_{m=1}^{M} dr_{C_i} + \sum_{n=1}^{N} dr_{D_{jTX}} + \sum_{MH=1}^{MH} dr_m \quad (13)$$

V. PROBLEM FORMULATION

First objective of this paper is to select the finest probable route in the multi jump D2D communication. In another detached we tried to find out optimized network throughput by looking at different algorithms. The path chosen for multi hop D2D communication is built on the Q learning algorithms which are projected in [16]. We have considered the present D2Dnode has n_j neighbouring nodes. The set of adjacent nodes $K_i = \{n_1, n_2, n_3, n_4, \ldots \ldots n_k\}$. According to the distance it provides the reward and continuously updates the Q table. The reward is intended for numerous knots from source to the end. The node which provides maximum reward to reach the target is considered as the best relaying path.

The objective functions that are mentioned above are subjected to following constraints.

$$\sum_{j=1}^{J} Dt_j = 0 \quad (T1)$$

$$\sum_{ki=1}^{K} x_{k_i} \geq 1 \quad (T2)$$

$$I_n + I_m \leq I_{threshold} \quad (T3)$$

$$\delta_c \leq \delta_{THRESHOLD} \quad (T4)$$

$$\delta_{D2D} \leq \delta_{THRESHOLD} \quad (T5)$$

$$P_C \leq 0 \quad (T6)$$

$$P_{D2D} \leq 0 \quad (T7)$$

The constraint T1 states that the midway knots in the transmit track do not have any documents to upload. The constriction T2 depicts that one d2d consumer can share just one resource chunk. T3, T4, T5 states that the intervention happened in the cell must be less than the inception intervention. T4 states that SINR of cellular user must be less than threshold SINR. T5 states that SINR of D2D must be less than threshold SINR. The power of the cellular consumer and D2D devices should be a smaller amount than system's extreme power. T6 and T7 denote that power allocated to the D2D devices and the cellular user must be greater than zero.

VI. METHODS

This paper has been divided into two stages. First stage deals with path selection. Q learning algorithm is used for relay selection for D2D communication. In the next stage maximization of throughput is done considering particle swarm optimization technique and gravitational search algorithm.

Stage 1: selection of path for multi hop D2D communication

Q- Learning provides an optimized solution for the problem of multi jump D2D communication way assortment. Here we have well-thought-out only one pair of D2D will be energetic at one interval. Here action assortment procedures have been used for the agents which are discovering through the key space. It mainly defines the action which is related to the specified state. The action taken is completely based on reward it will receive. A Q table has been maintained by the algorithm which gets updated by the reward matrix. Here D2D users are the agents from source to the target in the relay path and it interrelates with the surroundings. The environment in this scenario is the distance between each node and the SINR of each node. Different situations of the users are their states or the present and next node in the relay path. The action taken by the D2D user at a state will provide reward signals by the environment. Here minimum distance between the nodes will calculate the reward. This forms the basis of sequential learning. We have considered D2DTX node is the transmitting its data towards the next node D2DRX (). At the time t=0, the present node is D2DTX () and the receiving or the next node is D2DRX (). In Next time instant t=1, D2DRX () will be the transmitting node i.e D2DTX1 or we can say it is our present node and D2DRX1 will be our next node. Until the destination is reached this process continues. Figure 3 depicts the state figure for the relay path. If the next hop has better rewards than jumping on the base station directly then the action will be selected. The rewards will be provided to the nodes when all the actions are evaluated. We have considered 'N' cellular users and one base station. All the knowledge of the user node is provided to the base station. The cell considered is the circular and the base station is located at the focus (0,0). Distance between the node points D2DTX (X_i , Y_i) and D2DRX (X_j , Y_j). The Euclidean distance

$$Dist_{DTX\_DRX} = ((X_j - X_i)^2 + (Y_j - Y_i)^2)^{1/2} \quad (14)$$

$$R = \min (Dist_{DTX\_DRX}) \quad (15)$$

$$R = \frac{1}{Dist_{DTX\_DRX}} \quad (16)$$

For rudimentary Q learning procedure, the discount factor ϒ is taken 0.7. The merging rate α has a collection amid [0, 1]. 0 learning rate indicates no knowledge and 1 signifies quick learning. Here we have considered α =0.9. The worth repetition function is given as

V(S) = max. Q (D2DTX, A) (17)

Where A is the action and Q (D2DTX, A) represents the approximation parameter which is how worthy it is to take the feat A when the state is D2DTX. The agent will take an action and observe the reward and according to the reward it will transmit to another state.

{D2DTX1, A0, R0 D2DRX, A1, R1 D2DTX2, A2…..}

The action is a dependent parameter and it is dependent on reward function. According to the extreme of the reward function, action A will be chosen.

A α max(R) (18)

After the achievement of one whole age D2DTX, A0 gets reorganized by the given equation

Q (D2DTX, A0) = Q(D2DTX, A0) + α(R + ϒ max (A)) (Q(D2DRX, A1))-(Q(D2DTX,A0)) (19)

From the above it is concluded that the current state is D2DTX and if A0 action is chosen by the user, then it will land to state D2DRX. At D2DRX the possible action is A1 and the reward obtained is R which is given by the surroundings in response of action A0. The following flow chart is provided.

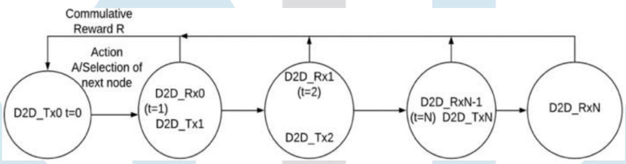


Fig 2: path states for multi hop D2D relay with action, state and reward functions

Stage 2 : Throughput maximization

To accomplish throughput maximization, we have tried to compare three optimization techniques that are particle swarm optimization, Gravitational search optimization and rapid particle swarm optimization. Algorithm 2 provides the pseudo code for finding the optimal solution.

Particle Swarm Optimization

According to the PSO methodology, Zi is the position of the particles, represents the set of power assigned to CU and D2D users.

$$Zi = [P_{D2D1}, P_{D2D2}, P_{D2D3} \ldots\ldots\ldots P_{D2DJ}, P_{C1}, P_{C2}, P_{C3} \ldots\ldots\ldots P_{CJ}]$$

The velocity of the particles is given as

$$V_{i+1} = W + V_i + C_1 r_1 (Pb - Zi) + C_2 r_2 (gb - Zi) \quad (20)$$

The inertial weight is given as w. r_1 and r_2 denotes the random number evenly spread over (0, 1). C_1 and C_2 are determining factor. The inertia w uses linear differential reducing inertia weight strategy. The method for the calculation is given as

$$W = \frac{W_{start} - (W_{start} - W_{end})L^2}{N^2} \quad (21)$$

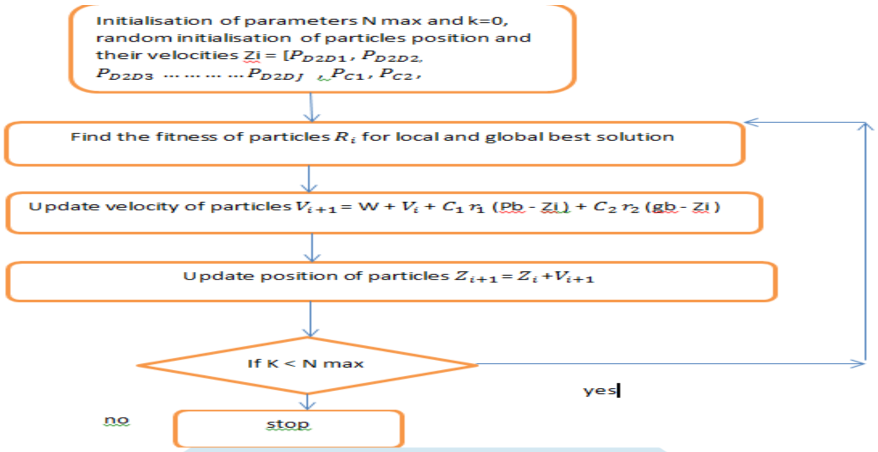


Fig 3: flow chart of PSO

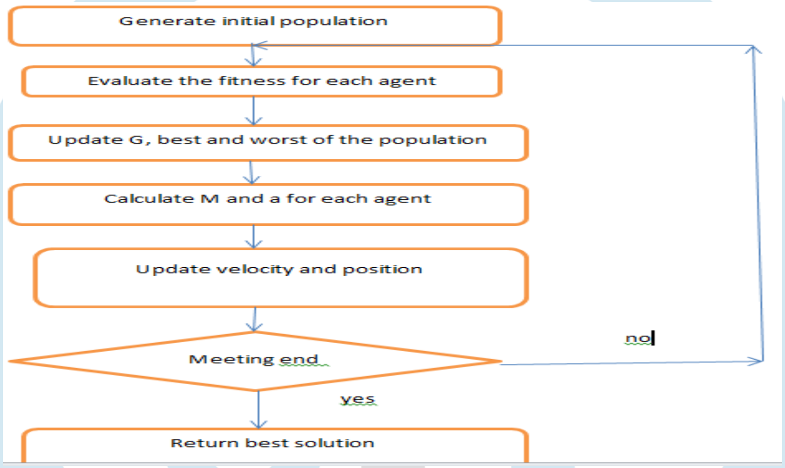


Fig 4: GSA flow chart

Abbreviations and Acronyms

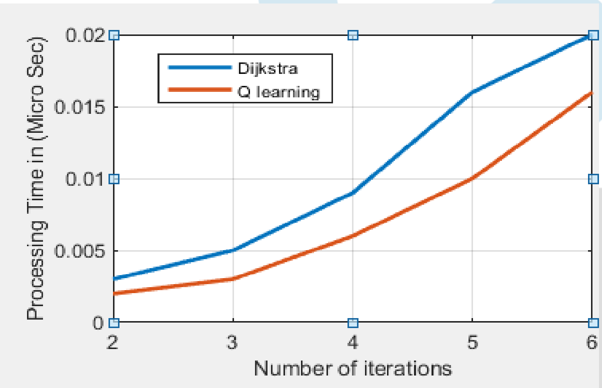
Notation	Parameters
δ_{C_i-eNB}	SINR at BS from cellular user
δ_{DjTX}	SINR at d2d transmitter side
dr_{C_i}	Throughput for cellular user
$dr_{D_{jTX}}$	Throughput for D2D user
I_m	Interference of cellular user
I_{eNB}	Interference at base station
I_n	Interference between D2D Tx and RX
I_T	Total interference of the system
δ_{MTX}	SINR at multi hop relay Tx
δ_{MRX}	SINR at multi hop relay Rx
δ_{s_r}	End to end SINR for multi hop communication
dr_m	Relay throughput
DR	System throughput
D2DTX	D2D transmitter
$Dist_{DTX\_DRX}$	Distance between D2D TX and RX
R	Reward
P	Resource sharing indicator
A	Learning rate
ϒ	Discount factor
V_{i+1}	Velocity of particles for consumers
Pb	Personal best
Gb	Global best

VII. SIMULATION RESULTS

The replication is carried out 300 whiles continuously using Matlab and values accomplished are contrived. The trial results for the Q learning process for path choice are compared with the dijkstra algorithm method. The outcomes show that Q- learning method outperformed in all the cases. Figure 5 depicts that when the number of the iteration are minimum i.e from 2 to 6 both the algorithm performed well. As we increased the number of iterations the processing time also increases. So from this it is concluded that Q- learning method outperformed in all the two cases. Figure 6 shows the throughput of the system versus numerous iteration in case of PSO. The throughput by PSO and GSA has been compared in figure 7. In this case GSA achieved the maximum optimal position of throughput which is greater in comparison to the PSO. The total number of iteration considered is 500. Below 45 iteration PSO performed better than GSA. Figure 8 shows the comparison between the processing time of GSA and PSO when number of request is varied up to 50. It is concluded from the figure that GSA processing time is far better than PSO.

Model structures

Description	Value
Number of total users	25
Extreme vicinity distance	80m
Noise power	10^{-3}
Power of D2D	1mw
Power of cellular user	100mw
Learning factor	0.7
Discount factor	0.9
Maximum iteration	300
Inertial weight	[0.4 0.9]



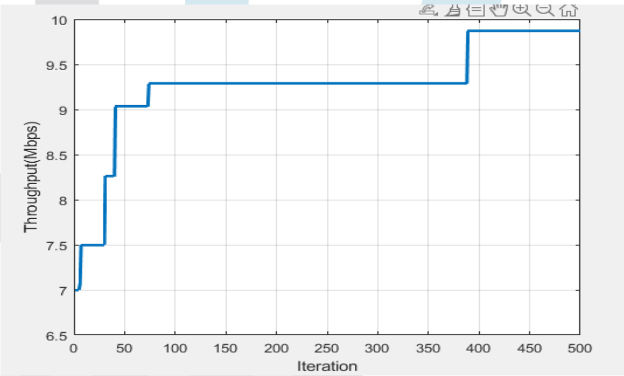
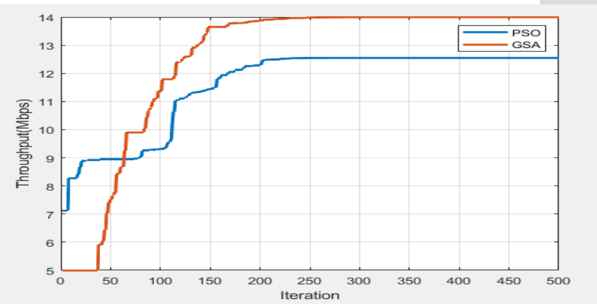


Fig 5: Processing time for the minimum number of iterations   Figure 6: Network throughput vs. Maximum iteration for PSO



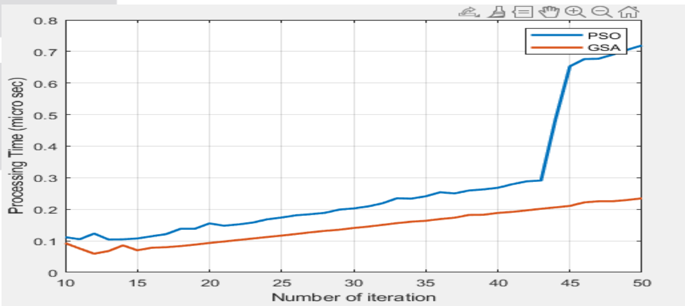


Figure 7: Network throughput vs. Maximum iteration   Figure 8: PSO and GSA processing time vs. number of requests graph

VIII. CONCLUSION

In this paper, we have fixated on path choice and throughput maximization techniques for multi hop D2D communication. Q learning model has been used in order to find out the best path conceivable from source to destination. The cumulative reward for all the nodes from source to the destination has been considered by the base station. To achieve network throughput. We have applied three algorithms PSO and GSA are tried to find out the best among them. The model results proved that GSA performed better compared to PSO. The future prolongation of this work can be the study of battery life of D2D individual nodes and application of another optimization schemes to improve the network throughput.

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