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R3-SVD: an Efficient R3 Optimization Technique for Improved Video Streaming Using Singular Value Decomposition and PSO Approach in Peer to Peer Networks

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Abstract: To improve the performance of video streaming in peer to peer networks an efficient R3-SVD technique is discussed in this paper. The Rate-Route-Resolution with Singular value decomposition technique uses the streaming rate, transmission route properties and video quality as the factors to choose a single route to transmit the video stream. The selection of transmission path is performed using singular value decomposition and particle swarm optimization technique. The earlier methods consider only few parameters to choose the transmission route and the route selection is optimized using PSO technique. The method identifies the routes available in the network to transmit the video stream and computes video streaming factor. Computed video streaming factors are constructed in the form of SVD matrix and the SVD technique selects a diagonal route from the matrix. The selected routes are optimized using particle swarm optimization technique where the optimization is performed based on video streaming factor. The inclusion of singular value decomposition technique with the support of R3 measures improves the video streaming performance up to 98%.

Key words: Video Streaming · SVD · PSO · R3-Optimization · Peer-Peer Networks

INTRODUCTION

The peer to peer network, which is unstructured in topology with large number of nodes. The data transmission in such peer-peer network is performed in a cooperative manner where each node can perform routing of packets. The application of peer-peer network has no limit and when the network becomes distributed the nodes of peer-peer network can be used to store huge amount of data. The nodes of the network are connected with different bandwidth connections and have varying bandwidth between them. In different situations, the organizations maintain many valuable in peer to peer networks and can upload or download from the network by routing techniques [1].

For any source S, to reach the destination D, there may be a K number of routes present in the network. For each route r, there exists h number of hops present in between the source and destination. Among them, between any two peers Pi, Pj there will be a communication channel which is connected by any protocol like wired or wireless. Whatever the connection or protocol being used, the communication channel has many properties like bandwidth Bw, data rate Dr, uplink Ulc and downlink capacity Dlc. So that before selecting any route to transmit the data packets, the route selection approach has to consider the above mentioned factors. Not only the above discussed factors, also there are other factors which affect the data transmission are channel Traffic, Packet Payload and so on [2].

Video streaming is the process of transmitting any video content V_i between any two peers P_i, Pj. If there exist a K number of routes between the source P_i and destination P_j, then the method has to select a single route from the available K routes. For each route R_i from available K routes, there exist an H number of intermediate nodes and between each pair of peers there will be a duplex link with the bandwidth Bw, Uplink capacity Ulc and downlink capacity Dlc. With the factors of duplex link, the video stream factor can be computed using transmission frequency, payload of any route. The video streaming factor represents the depthness of any route entry in supporting video transmission [3].

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The video streaming problem in peer to peer networks could be handled with the support of hybridized singular value decomposition and particle swarm optimization methods. In general SVD approach, the method takes an input of matrix and selects a diagonal matrix as a result. The method identifies and orders the dimensions where the data points have more variation. By identifying the dimension which has more variations, then we could identify the best approximation from the original input data points. So the problem of data reduction can be approached with the help of SVD technique. The same beauty can be applied for the problem of video streaming where the route selection has to be performed in efficient manner. By presenting the routes through different neighbors in form of matrix, the SVD technique can approximate and reduce the number of efficient routes, from which the method can choose best possible route [4].

Here in order to verify the approximated route according to different parameters the Particle Swarm Optimization method can be applied. The PSO is a population based optimization technique, which is initialized by random populations. Then the method searches for optimal solution by updating generations. In this approach, each particle computes fitness value for different parameters using which a best particle is selected. Such a powerful solution can be applied to solve the problem of route selection in video streaming. The result of SVD technique can be given to the PSO technique which can optimize and select most efficient routes according to the fitness value computed. By hybridizing SVD and PSO for the problem of route selection to support video streaming, the efficiency of video streaming can be improved [5].

The R3-SVD is the technique of computing video streaming factor of any route identified and by computing video streaming factor of all identified routes, they can be formulated as a matrix. From the matrix of video streaming factor, the SVD technique can be used to choose a small set of routes. The singular value decomposition is the method of choosing a diagonal links from the matrix. From the small set of route links, the popular particle swarm optimization technique can be used to choose the best route. The PSO technique uses the video streaming factor as the deciding factor and selects most optimal route to perform video streaming [6].

Related Works: The problem of video streaming in peer to peer network has been studied in many research articles. Each of them has their own method of video streaming and this section discusses about the articles being compared and methods being explored towards the problem of video streaming.

In [7], an efficient bandwidth allocation technique has been discussed to improve the performance of video streaming in wireless local area networks. The smart mobile devices which have facilities to perform video streaming towards IP based wireless networks. The popular 802.11 protocol standards have been updated to support live video streaming in different networks. Other than different networks the peer-peer networks has great support in video streaming and produces more efficiency. The approach discusses about the allocation of bandwidth for the peers to support greater video streaming.

The methods of video streaming in peer-peer have been well studied in [8], which addresses, interactive service handling and consider the network changes in different times. The paper analyzes the server stress in providing interactive services of VOD streaming. The paper also addresses the issue of on demand video streaming capabilities of different methods [9].

In [10], the author discusses the problem of video streaming startup and getting the initial offset of video while performing live video streaming. In this approach, the author discusses a chunk based video streaming and initial buffer status at the startup time. Also, two different offset has been specified namely, fixed padding and proportional padding which works based on the streaming conditions. In case of fixed padding mechanism, the value of the offset is set by the neighbor peer where as in case of proportional method the offset is set according to the streaming conditions [11].

A smooth cache live video streaming for peer-peer video streaming has been discussed in [2], where the method uses the HTTP protocol to transfer the video content. Also the method is flexible to transfer data at a variable data rate. In order to overcome the issue of congestion in the network, the method proposes a caching mechanism which supports smooth transfer of video stream according to requirement. This approach reduces the problem of congestion in video streaming and improves the efficiency of video streaming. In [3] in incentive based bandwidth allocation scheme has been discussed. The method, use a distributed method for streaming video bits from different nodes of P2P networks. This approach is designed towards increasing the bandwidth utilization and focused on prioritizing the request according to the content of the video.

A collaborative video sharing approach is discussed in [4], which enables storage of video blocks in persistent storage and distributing them or exchanging between peers at a later stage. This approach enables video streaming by time shift and on demand nature of video streaming. This supports the slow downstream and make easier for the peer to download with slow speed. Also the paper addresses the problem of wait and playback or wait for the download to complete.

An ant-based rate allocation algorithm for media streaming in peer to peer network [1], has been discussed which extends the session orient approach in dynamic networks to the next level. The rate allocation method works over an ant colony and decides the streaming quality and sending rate, according to the conditions of the peers. The method uses network dynamics to compute the speed of video streaming and rate of stream allocation. This method is helpful where the peer has uncertain properties [12].

An efficient content distribution scheme has been discussed in [5], to improve video streaming in high quality. The method combines the architecture of peer-peer networks with server based networks with the same functionality. The method proposes a different content distribution model with hybrid nature to distribute video chunks over the participants. This improves the performance of video streaming [13] where there are fast/slow peers in the network. In order to matching P2P logical overlay network with physical topology, the position-based topology has been proposed in [9]. The method considers various features of video streaming to improve the quality of service at different levels.

A topology based video streaming technique has been discussed in [14], which uses network meta data and uses layer based video streaming. The method considers the quality of video being received and number of users receives the quality video. Also the method concentrates on how the number of users can be increased and to achieve that the method deploys the video content in different locations of the network to maximize the video streaming efficiency.

Energy-spectrum efficiency tradeoff for video streaming over mobile ad hoc network [6], proposes a scheduling algorithm which considers the efficiency in energy and efficiency in spectrum to perform video streaming in Manet. The author has demonstrated the scenario using a random walk model where there is no restriction for the mobile nodes for their mobility. Also the author has validated the efficiency of video streaming in the random walk model where the nodes have different velocity and directions.

Impact of execution time on adaptive wireless video scheduling [9], discusses a scheduling algorithm to optimize the stochastic conditions. The method connects the time and video quality to improve the performance of video streaming. The scheduling algorithm counts the time taken and video quality streamed to perform scheduling. In [10], the author introduces an efficient content fetching mechanism which is applicable in video streaming in wireless networks. The method monitors the changes in one hop neighbor and estimates the stability of nodes to support video streaming. To improve the efficiency of cooperative video streaming efficiency the method computes the link reliability and intimates the bandwidth conditions in the network. The proposed algorithm supports improvement of video streaming performance [15].

From the above discussion, it can be concluded that the methods discussed above have many issues in performing video streaming in wireless adhoc networks.

Problem Statement: The problem of video streaming in wireless adhoc networks has been analyzed and the methods discussed have been verified for their efficiency in video streaming. From the analysis a number of issues have been identified as listed below:

The methods use shortest path to stream video content in peer-peer networks, where selecting shortest path will not be fair in all the situation, because the route may be congested in most times and this will increases the traffic in particular route and increase the latency also.

Selecting the route is the main issue in video streaming, but has been focused only in few papers analyzed. Even though, the methods use only the hop count to choose the path or they use only minimum factors to choose the route.

The methods do not consider the variable bandwidth conditions and misses the other factors of video streaming like data rate, route factor and transmission frequency.

Identified problems have motivated us to design and develop a more strategic approach, which helps to improve the performance of video streaming in wireless adhoc networks.

R3-SVD with PSO Based Video Streaming Technique: The R3-SVD technique computes the available routes in the peer-peer networks at the first stage. In the second stage, the method computes video streaming factor for each route identified. The computed video streaming factor is converted into a singular value matrix and applies the SVD technique. Then the method selects a small set of diagonal routes from the SVD matrix which is then optimized using particle swarm optimization technique. The complete process has been split into different functional names like Route Discovery, Video Streaming Factor Computation, SVD Computation, PSO based route optimization. This section briefs each functional stage in detail later.

Route Discovery: For any source Si given, the method performs route discovery by sending route request. The route request message is multicast into the network and the node waits for the route reply from the neighbor identified. The route request message is flooded into the network and finally the process stops when the source receives reply from all the neighbors. Then the source node extracts all the possible routes identified and updates the route matrix. The route reply has three different messages, namely bandwidth of the channel, data rate and number of neighbors. The source node extracts the three factors with the route and updates route table and node factor table. Updated route factor table and route table will be used in the next stage to compute the video streaming factor.

Algorithm:
Input: Route Factor Table RFT, Route Table Rt, Neighbor Table Nt
Output: Route Factor Table RFT, Route Table Rt
Start
Initialize Route factor table RFT.
Initialize route reply count RRC.
Generate RREQ message.
for each neighbor Ni from Nt
Send RREQ message.
End
Receive Route reply RREP.
RRC= RRC+1.
while RRC!= sizeof(Nt)
Receive Route reply RREP.
Extract available routes from RREP.
Route set Rs = Σ *Routes* $\in$ *RREP*
for each route Ri from Rs
Factor F = $\int_{i=1}^{size(Rs)} \varnothing\{Bw, Tr, Ulc, Dlc, NN\}$
RFT = $\Sigma(Fi \in RFT) \cup F$
Rt = $\Sigma(Ri \in RT) \cup Rk$
End
End
Stop.

The route discovery algorithm discovers the list of routes available in the network to reach the destination and extracts the route factors from the route reply being received.

Video Streaming Factor Computation: Video streaming factor represents the trustworthy of the route or suitability of the route for the transmission of video stream. There may be h number of hops present in the route and there will be different bandwidth conditions, traffic and channel capacity and neighbors. The method computes the video streaming factor from the factors considered and the computed VSF value will be used to select the route and transmit the video streams.

Algorithm:
Input: Route Factor Table RFT, Route Table RT.
Output: VSF set
Start
for each route Ri from Rt
compute Vsf = $\frac{Tr(Rft(Ri))}{BW(Rft(Ri))} \times \frac{Ulc(Rft(Ri))}{Tr(Rft(Ri))} \times \frac{Dic(Rft(Ri))}{Tr(Rft(Ri))} \times \frac{Tr(Rft(Ri))}{Nn(Rft(Ri))}$

Add to VSF Set VSFS = Σ ($Vsfi \in VSFS$) $\cup$ Vsf
End
Stop

The above discussed algorithm computes the video streaming factor each route identified and computed video streaming factor value will be used to perform optimization.

SVD Based Route Selection: The problem of route selection has been handled with the Singular Value Decomposition approach. The singular value decomposition is the technique of dimensionality reduction where the number of routes is higher in dimension. From the route table and the route factor table, the method generates the singular value matrix I at the first stage. In the second stage the method computes the transpose of the matrix. The method generates the singular value matrix with the number of rows equal to the number of neighbors. For each neighbor the method creates a row in the singular value matrix. Through each neighbor there will be N number of routes to reach the destination and base on the value of N, the method generates the number of columns of the matrix. If there are only a few routes for a neighbor, then the remaining columns will be placed with zero. In the second stage, the method computes the transpose of the matrix I and computes the ortho normal U and V^T from the input matrix I. Finally the method computes the ortho normal matrix for each matrix using the eigenvalues of the route factor matrix. Based on the result of the reduced dimensional route factor matrix a singular dimension will be selected.

Algorithm:
Input: VSF Set VSFS, Route Table Rt.
Output: Ordered Route Set Rs, Diagonal Row Dr.
Start
for each neighbor Ni from Neighbor table Nt
generate Rows in the singular value matrix.
SVM = $\int_{i=1}^{size(Nt)} SVM(Ri) \cup Tj\{\Sigma\, Routes(Ni,Rt) \uparrow VSFS(Rt)\}$
End
Compute Ortho normal Matrix U=SVM×SVM^T
Compute Eigen values $\lambda = (SVM \times SVM^T)\,[x1, x2, .. xn]$.
Apply normalization in U.
Compute Orthonormal matrix V= SVM^T×SVM
Apply Normalization on V.
Compute square root of Non-zero eigenvalues in U and V.
Arrange them in the diagonal matrix S.
Select the diagonal rows of S.
Diagonal Row Dr=Diagonal(S).
Stop.

The above discussed algorithm computes the singular value decomposition of the route matrix using the video streaming factor set computed in the previous stage.

R3-SVD Based Video Streaming: This functional component performs the coordination of all the functional stages. Whenever a source node has the video stream to be transmitted, first the method performs route discovery and for each route in the route table, the method computes the video streaming factor. Using both computed values, the method generates the Singular Value Route Matrix. The generated SVRM will be used to perform SVD for dimensionality reduction, which returns a single diagonal value. Using the diagonal value, the method selects top few elements and for each route the method computes the R3-Weight which will be optimized with PSO technique. Based on the weight the stream will be regulated in multiple routes.

Algorithm:
Input: Neighbor Table Nt, Route Table Rt
Output: Null
Start
Route Table RT = Perform Route Discovery.
VSFs = Perform Video Streaming Factor Estimation.
Diagonal Dr = SVD(RT, VSFS)
for each route Ri from Dr
Compute R3-Weight.
R3-W = $\int_{i=1}^{size(Rs)} VSFS(i) \times \mu$
Perform PSO(R3-W).
if R3W>HTh Then
Stream High Quality Video.
elseif R3W>MTh && R3W<HTh then
Stream Medium Quality Video.
else
Stream Low Quality Video.
End
End
Stop.

The above discussed algorithm performs the complete process of the proposed approach and performs different video streaming in an efficient manner.

Experimental Setup: The R3 singular value decomposition based video streaming approach has been implemented using java and has been tested for its efficiency using the following setup mentioned.

The simulation details has been presented in Table 1. The method has been simulated and the performance of the method has been validated using the above scenario considered.

Case Study: The R3-SVD technique has been tested with the following scenario.

The Table 2, details the testing scenario taken to evaluate the performance of R3-SVD technique. The user U has generated a request Ui where the requested resource is Ri. The Ri denotes the instance of video V.

The R3-SVD algorithm receives the user request Ui and identifies the list of peers contains the requested resource Ri. Then the algorithm identifies list of routes present in the network to reach the resource peers. Finally the method computes the streaming support factor for each route and performs singular value decomposition to choose an efficient route. The route selection is performed based on the streaming support factor and the quality of streaming required.

Table 1: Details of simulation

Parameters	Value
Peer Nodes	300 Numbers
Resource Nodes	10 Numbers
Window Size Selected	4
Requests	200 numbers

Table 2: Detail of testing scenario

Resource Name	Vi an instance of video V
Number of locations stored	K
Total Number of nodes in Network	300

Table 3: Details of route selection

Resource Peers	Routes	Video Streaming factor	R3 Weight	Route for quality
20	1-2-8-9	9.3	6.51	Higher
	1-3-7-10-9	8.2	5.74	Moderate
	1-3-5-12-13	6.8	4.76	Low
14	1-3-7-10-14	6.8	4.76	Low
18	1-3-5-12-17-18	4.1	2.87	No
20	1-3-6-11-16-19-20	1.6	-5.4	No

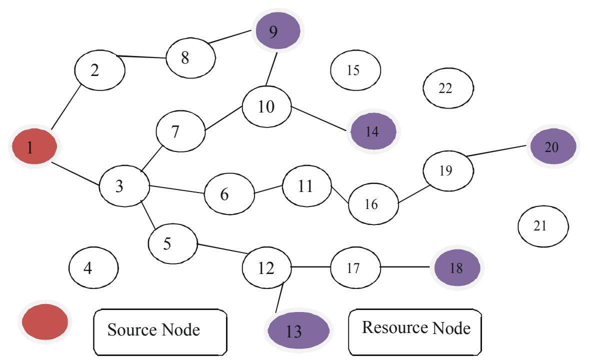

Fig. 1: Snapshot of network considered

The network topology considered for the test case has been shown in Figure 1. In Figure 1, there are 21 nodes present in the network and three of them act as resource peer. To reach each resource peer there are different routes available for the requesting node. The details of routes for each resource peer have been shown below.

The routes available for the requesting node 1 to reach the resource peers has been displayed in Table 3. Using the routes available, the method computes the video streaming factor for each of them. Computed video streaming factor has been displayed in Table 5. The Table 5, also shows the R3 weight computed based on the singular value decomposition approach. Using the R3 weight computed the method choose a single route to perform video streaming.

RESULTS AND DISCUSSION

The proposed R3-SVD based video streaming has been implemented in advanced java and the method has been evaluated for its efficiency using different scenarios. The performance of the proposed method has been measured and compared with other methods. The details of implementation have been displayed below:

Table 4: Network Topology Considered

Parameter	Value
Number of nodes	200
Average Number of neighbors	5
Average Number of routes	70
Simulation Area	2000×2000 Meters

The details of network topology and simulation scenario considered for the evaluation of R3-SVD technique has been shown in Table 4. For the evaluation purpose, the method has been measured for the following parameters.

The streaming efficiency is computed based on the number of bits being transferred in specific time T. The streaming efficiency can be computed as follows:

$$ST_{eff} = \frac{Total\ Number\ of\ Bits\ Transfered}{Time}$$

The method has been evaluated for video streaming efficiency and the result produced by the proposed method has been compared with other methods. The comparative analysis shows that the proposed R3-SVD technique has produced higher video streaming efficiency than other methods.

The efficiency of video streaming algorithm depends on the streaming latency also. So that the proposed algorithm has been analyzed for its steaming latency. Also the result produced by the proposed algorithm has been compared with other methods also. The comparative result shows clearly that the proposed algorithm has produced less latency than others as shown in Graph2.

The efficiency of video streaming is also based on the resource utilization and how the bandwidth has been occupied. To evaluate the efficiency in resource utilization of proposed algorithm several tests were made. The result has been compared with the other algorithms. The result shows that the proposed method has produced more bandwidth utilization efficiency than others.

The Table 3 shows the comparative results on various parameters produced by different methods. The values show that the proposed method has produced more efficient results than other methods.

Table 3: Comparative analysis of various parameters

Method Name	Streaming Accuracy	Streaming Latency	Bandwidth Utilization
P2PVOD	83.4	79	79
P2PLS	86.5	64	81
Incentive Based	89.4	46	84
R3-SVD	97.8	21	97.6

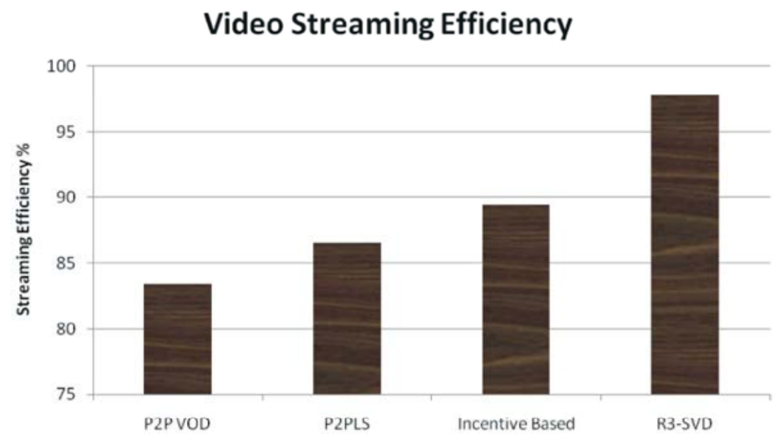

Fig. 2: Analysis Result of video streaming efficiency

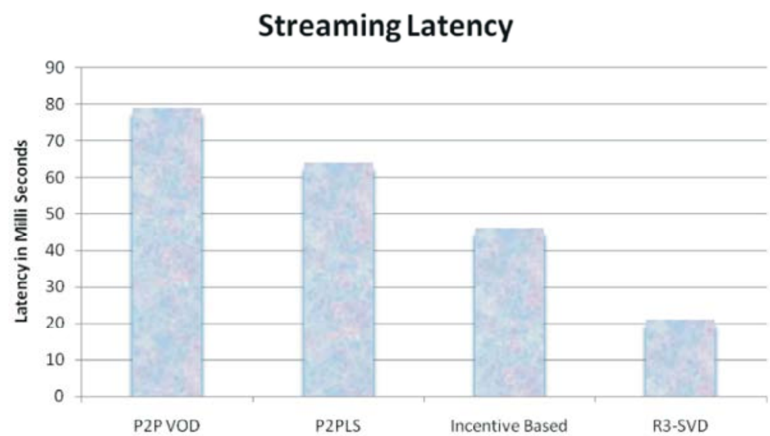

Fig. 3: Analysis result of streaming latency

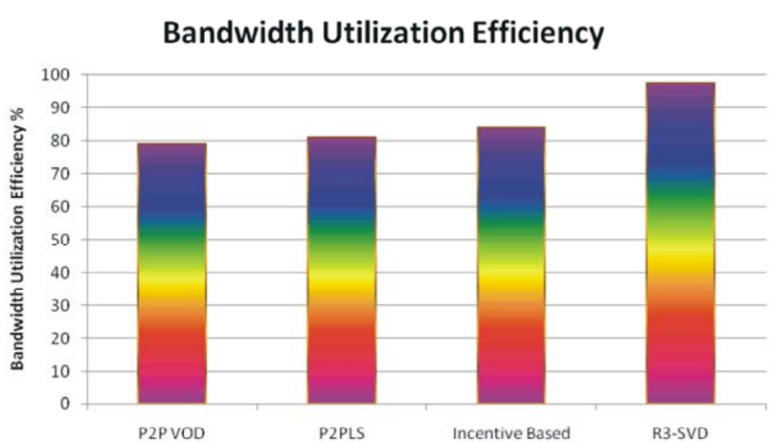

Fig. 4: Analysis result of resource utilization efficiency

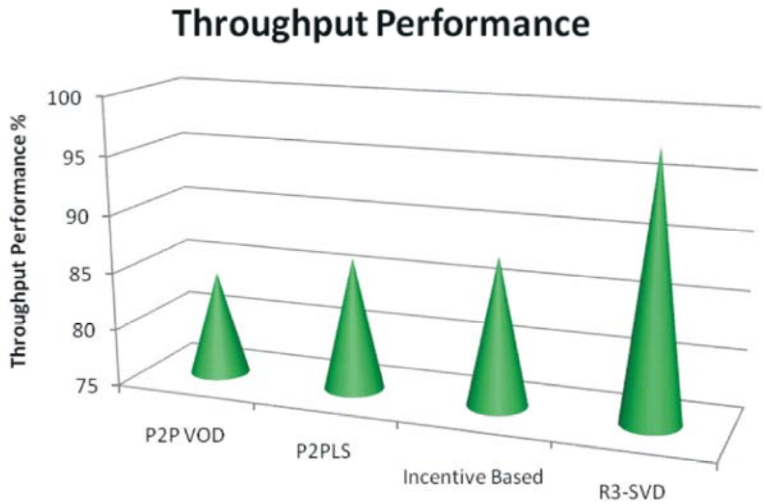

Fig. 5: Analysis result on throughput performance

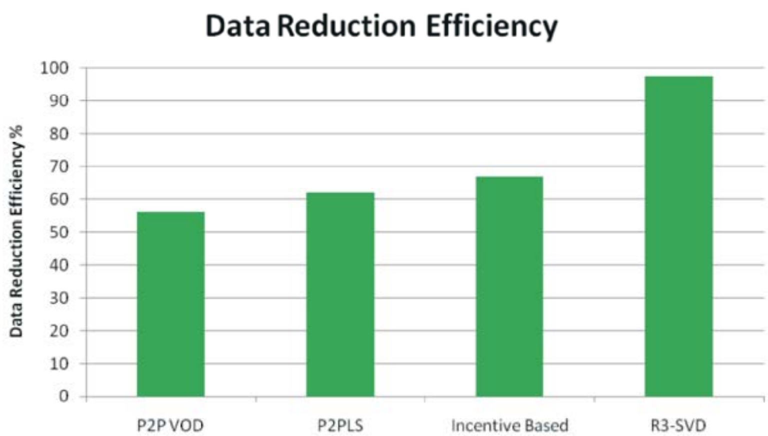

Fig. 6: Analysis result on data reduction

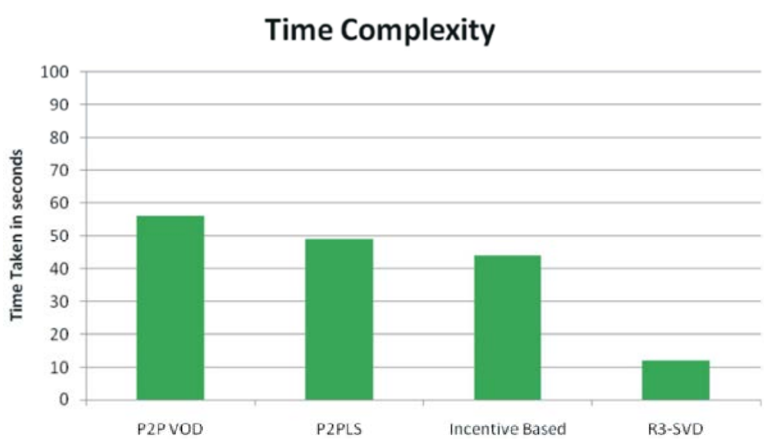

Fig. 7: Analysis on time complexity

The Throughput is the measure which represents the outcome of any algorithm. The proposed algorithm has been measured on this parameter and compared with other methods. The results shows the proposed algorithm produces better performance than other methods.

The efficiency on data reduction has been measured for the proposed algorithm and compared with others. The result of comparison has been shown in Figure 6 and the proposed algorithm has produced higher data reduction than others.

The comparative study on time taken has been performed and the proposed algorithm has introduced less time value than others.

The proposed R3-SVD based video streaming approach identifies various routes and among them it chooses a small set of routes which has more bandwidth, less traffic and minimum hops to transfer the video. This reduces the latency of video streaming and selecting multiple routes based on the result of SVD technique helps utilizing the available routes and channel capacity in a more efficient manner. This behavior increases the channel utilization and increases the throughput also.

CONCLUSION

This paper proposes an efficient video streaming technique for peer-peer networks named R3-SVD with PSO. The method first identifies the available routes whenever there is a video to be streamed. For each route being identified, the method computes the video streaming factor using the factors of the channel, traffic and hops present in the route. The route table and the video streaming factor are used to generate the singular value matrix. Then the SVD technique is applied to the singular value matrix and selects the diagonal matrix by reducing the dimensionality of the input matrix. Each route selected in the SVD technique is optimized using PSO technique with the support R3-weight. Based on the weight of the route selected, the method streams the video in different properties. The approach improves the performance of video streaming and reduces the streaming latency.

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