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Parameter Value Optimization of Ad-hoc On Demand Multipath Distance Vector Routing using Particle Swarm Optimization

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Abstract

The performance of routing protocol in Vehicular ad-hoc network (VANET) depends on value of parameters used in. Being very large combination of these values, it is difficult to find an optimal combination for better QoS in VANET. Therefore, we have proposed an algorithm based on Particle Swarm Optimization (PSO) to find an optimal combination in Ad-hoc on demand multipath distance vector routing (AOMDV) in real scenario. The experimental results show 80.65% drop in Average End-to-End delay (AE2ED), 37.07% drop in Network Routing Load (NRL) and slight drop (1.96%) in Packet Delivery Ratio (PDR) using optimal combination of value of parameters.

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1. Introduction

Vehicular ad-hoc network (VANET) is one of the research areas of mobile ad-hoc network (MANET) with some limitations like road constraint, speed of vehicles etc. The formation of VANET takes place by moving vehicles in particular direction. The advantages of VANET are several - road side assistance, safety of drivers, dissemination of information regarding any mishappening on the road etc. Spreading the message requires communication among running vehicles. Therefore, the routing of message becomes important in VANET. Each vehicle in VANET has

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onboard system, which provides the necessary environment for communication among vehicles. These systems have routing protocols for the dissemination of message.

Researchers in the area have proposed many routing protocols as reported in the literatures. These protocols which are based on their nature of working are divided as proactive and reactive. Proactive routing protocols, or table driven protocols are those which keep a path between source and destination ready all time for communication before a source wishes to send the message. Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR) etc are proactive routing protocols. Reactive routing protocols or on demand routing protocols try to establish a path when the source is required to send the message to the destination. Reactive protocols are Ad-hoc on demand distance vector routing (AODV), Dynamic Source Routing (DSR) etc. It is seen that most application of VANET critically relies on routing protocols. The performance of these protocols depends on the value of parameters used for evaluation³. Therefore, the techniques that can determine the optimal value of parameters for the protocol before deployment may be used. Optimal value of parameters will improve the Quality of service (QoS) in VANET.

In this paper, we have defined a strategy that solves the problem of determining the optimal value of parameters to improve the QoS. We have chosen AOMDV routing protocol since it has many features. One of such feature is that it keeps communicating via alternate path available when there is link breakage between source and destination. AOMDV presents reduced end-to-end delay and increased PDR as compared to AODV. The control packets used in the protocols create congestion and depend on value of parameters. Therefore, we have used meta-heuristic for finding the optimal value of parameters. Meta-heuristic is used to solve the optimization problem in many other areas of engineering.

An optimization problem is defined in terms of search space, i.e. the number of possible solutions (also known as solution vector). There are nine parameters in the AOMDV which are responsible for the performance of VANET and each parameter has some specified range. Therefore, the possible combination of values of parameters is large and finding the optimal value of parameters in the search space is a very complex task. This problem is also known as a combinatorial optimization problem. Although many meta-heuristic algorithms are used to solve the similar combinatorial optimization problem in a multitude of engineering disciplines but very limited application of meta-heuristic is observed in ad-hoc network, especially in VANETs. Some of the applications are as mentioned below.

In¹, genetic algorithm is used to find the optimal broadcasting strategy in MANET. In², the six versions of genetic algorithm (GA) were evaluated and used in the designing ad-hoc injection networks. In³, GA, Simulated annealing (SA), differential evolution (DE), Particle swarm intelligence (PSO) and Random meta-heuristic algorithms are used to tune the OLSR protocol by finding the optimal set of parameter values. In⁴, GA, SA, PSO and random meta-heuristic are used to tune AODV automatically. In⁵, multi-cast routing problem in MANET is solved by applying GA. In⁶, a new routing protocol designed using ant colony optimization is given. In⁷, file transfer service in realistic VANET scenarios, is optimized by using different meta-heuristic. In this paper, we are going to find optimal value of parameters for AOMDV protocol on VANET using particle swarm optimization (PSO). PSO⁸ is a heuristic global optimization method and is found by research on birds and fish flock behavior. This behavior is also known as swarm intelligence. This algorithm is chosen since its principle of working is inspired from swarm intelligence, which suites to the problem we are going to implement. The network simulator, ns-2⁹, is used as fitness function evaluator. It gets the value of parameters provided by PSO, and evaluates them to guide the PSO in the search space for finding tentative optimal value of parameters. A real scenario map of Noida sector 63, U.P., India has been taken so that the evaluation of AOMDV using PSO may become more realistic.

In this paper, our contributions are as follows:

- We have proposed a strategy to evaluate the performance of AOMDV using optimal value of parameters obtained using PSO.
- Mapping of problem into PSO.
- Implementation of PSO in C++ and integration of it with ns2.
- Real VANET scenario has been generated by downloading a real map using Java OpenStreetMap editor 10 and converted into a form which is supported by MOVE11.

The remainder of the paper is organized as follows. In section 2, an overview of the problem has been discussed.

Section 3 consists of a framework of optimization strategy. Section 4 describes VANET Scenario and Mobility Models used. Section 5 illustrates the experimental set up, mapping of the problem in to PSO. Finally section 6 gives the conclusion and future directions of research work that can be carried out in this area.

2. Problem Overview

In VANET, the communication between a source and destination takes place through multiple hops. The primary aim of communication is routing of messages. At run time, a path is established through multiple moving vehicles. If a vehicle moves out of communication range of another vehicle in the path, it results in disconnection of the path. For establishing and maintaining paths, vehicles (nodes) send or receive control packets. As the number of control packets increases, it affects QoS in VANETs. The control packets depend on the value of parameters used in the deployed protocol in VANET. Here, we have taken AOMDV protocol to deploy and test using PSO. The reason to choose AOMDV in VANET is due to its multiple features.

2.1. AOMDV

AOMDV is actually an extension of Ad-hoc on demand distance vector routing (AODV)¹² protocol. It uses the concepts of hop-by-hop and distance vector routing approaches¹³. AOMDV uses the same route discovery procedure as in AODV. But the difference is in the number of paths found between these two protocols. In AODV, a single path is discovered between a source and destination, wherein AOMDV, multiple disjoint, loop free, paths are discovered between a source and destination pair. Another difference is that AOMDV starts the route discovery process only when all discovered routes fail. Existence of multiple paths lets the protocol perform fewer route discoveries¹⁴ and results in reduction of packet loss by 40%, routing overheads by 30% and significant improvement in end to end delay¹³.

The AOMDV works in similar manner as AODV by using the four message sets. First, route request (RREQ) message is used to find routes from a source to destination. To accomplish this, AOMDV performs route advertisement and route acceptance which are not performed in AODV. The route advertisement and route acceptance¹⁴ help protocol in maintaining freedom from loops in paths. Second, Route reply (RREP) is one of the messages used to reply to the source from the destination or from an intermediate node, having a fresh path, from the node to the destination. Third, the notification of route failure is taken care by route error (RERR) message. The last one is link status monitoring that is done by exchanging HELLO message. There would be many paths found during the route discovery process but only disjoint paths are considered. As, AOMDV has been extended from AODV with some additional functions as discussed above, most of the parameters of AODV remain same in AOMDV. The parameters and their default values, mentioned in Table 1 are taken from AODV (RFC 3561)¹² and are used in AOMDV to optimize the value of these parameters.

2.2. Tuning of Parameters

The default value of parameters used in AOMDV offer moderate QoS. Therefore, considering the impact of value of parameters on the network performance, we try to discover an optimal value of parameters for AOMDV before deployment. There are nine parameters used in AOMDV as mentioned in Table 1. It can be seen from Table 1 that the number of possible combinations of value of parameters is very large (10^{11} sets). Further, testing of each set of value of parameters on ns-2 individually is impractical. This motivates us to use the meta-heuristic that is capable to solve the combinatorial optimization. The range of parameters given in Table 1 is considered based on the restrictions posed in AOMDV. To analyze the different sets of value of parameters (solution), we have used three well known QoS parameters which are defined below^{4, 15}:

- PDR – This is the ratio of the number of packets received at the destination and the number of packets sent by the source.
- AE2ED – This is average time duration taken by a packet in transmission from a source to destination.

- **NRL** – This is defined as the ratio of administrative routing transmission and data packets delivered. Here, transmission counting is done by counting each hop separately.

3. Framework of Optimization

The framework of optimization consist two parts - optimization algorithm and solution Evaluation as shown in Fig 1. In optimization algorithm, a new population (10 sets of solution vector) is generated by PSO and used in simulation for performance evaluation.

Table1. AOMDV Parameter and its default values-Extended from AODV(RFC-3561).

Parameter	Default Values	Range
ACTIVE_ROUTE_TIMEOUT	3.0S	1 to 10
ALLOWED_HELLO_LOSS	2 HELLO Packets	1 to 10
MY_ROUTE_TIMEOUT	2 x ACTIVE_ROUTE_TIMEOUT	1 to 10
NET_DIAMETER	35 Nodes	1 to 50
NODE_TRAVERSAL_TIME	0.04 s	0.01 to 1.00
RREQ_RETRIES	2 tries	1 to 10
TTL_START	1.0 s	1 to 10
TTL_INCREMENT	2.0 s	1 to 10
TTL_THERSHOLD	7.0 s	1 to 20

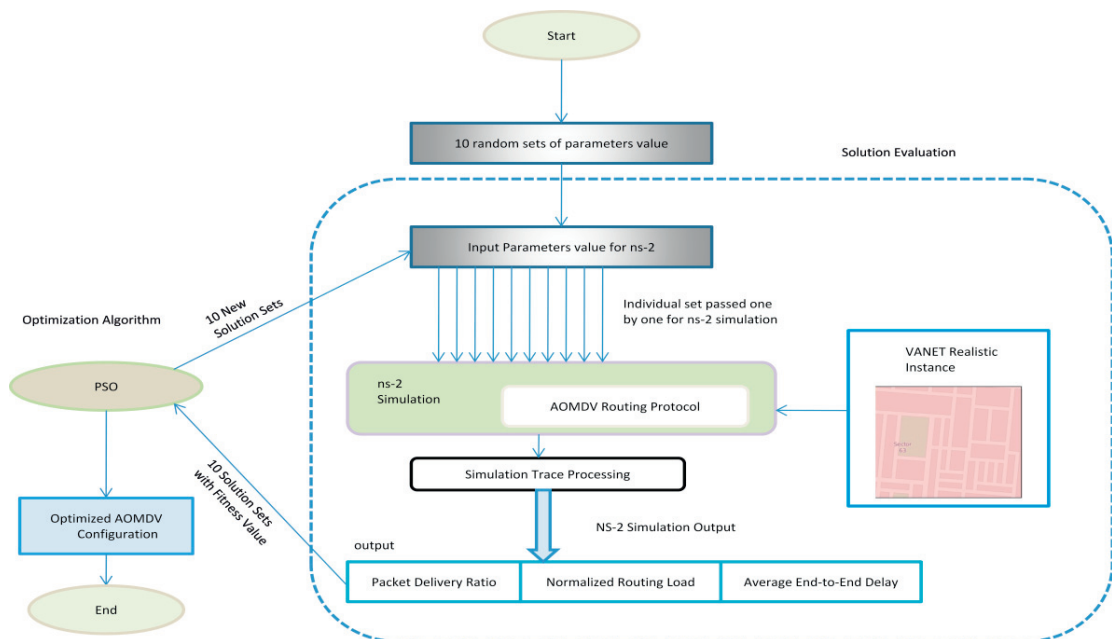


Fig. 1. The optimization framework for AOMDV using PSO. PSO invokes the ns-2 simulator for each solution evaluation.

The PSO tries to find an optimal value of parameters in the search space (solution vector). This optimization is carried out using a fitness function mentioned in the equation (1). The simulation model accepts a population from PSO and passes one by one solution (value of parameters) into AOMDV. Now, ns-2 takes VANET realistic instance and configures it according to AOMDV protocol and simulation parameters as mentioned in Table 2. The process of accepting a population from PSO is done automatically because ns-2 has been modified accordingly. ns-2 produces

global information, known as simulation trace. This information is used to calculate the QoS (PDR, NRL and AE2ED) parameters which are used for calculation of the fitness function. The fitness function is defined as follows⁴:

$$\text{Fitness} = w_2.NRL + w_3.AE2ED - w_1.PDR \quad (1)$$

The objective of this fitness function is to maximize PDR, and to minimize both the NRL and AE2ED. Equation (1) is the aggregate minimizing function and that is the reason PDR is used with a negative sign. The w_1 , w_2 and w_3 are used to weigh the effect of each QoS parameters on the resultant fitness value. The values of w_1 , w_2 and w_3 are taken 0.5, 0.3, and 0.2 respectively in the equation. Therefore, PDR gets priority over AE2ED and NRL. This is because, we are trying to maximize the PDR and minimize others (NRL, AE2ED).

4. VANET Scenario and Mobility Model

For carrying out experiments we have considered traffic/network simulator that can generate traffic – movement of vehicles, and communication activity. We have also generated realistic VANET environments (map) by selecting

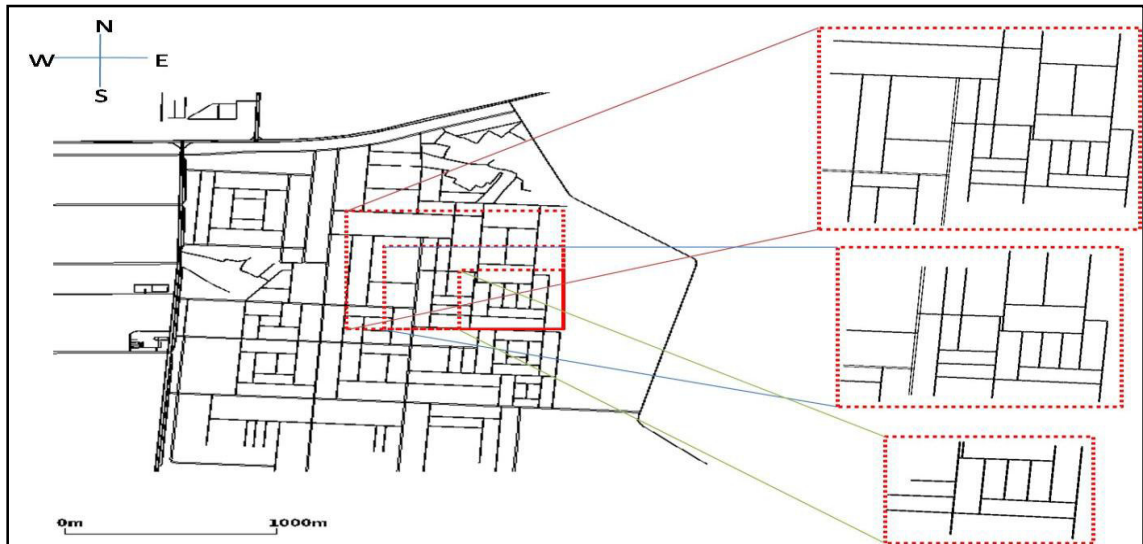


Fig. 2. Noida sector 63, India¹⁶ Real VANET Scenarios maximum. The selected Area is 1068m × 1075 m.

a real area from digital map available in¹⁶. On this map the actual road direction, and signal lights along with traffic rules are considered. Further, communication model and realistic mobility is used for each vehicle agent. In the simulation, we have generated a real map of Noida sector 63 UP, India (1068m × 1075m area) using Java openstreetmapeditor (A Java based software JOSM)¹⁰. Then using netconvert, the map (as osm file) is converted into the format supported by the SUMO traffic simulator¹⁷. The map of the area in reference is shown in Fig. 2. On this map, traffic in terms of number of vehicles, connections, turn, and flows is created. SUMO traffic simulator then generates TCL script for the traffic scenario. This TCL script is imported to ns-2 simulator. The parameters used in final ns-2 simulation are listed in Table 2. In the simulation, for data flow model, CBR is used as network application and UDP (user datagram protocol) as a source agent in vehicles. CBR packet size of 1000 bytes and bit rate of 64Kb per second is taken. In the simulation, we have considered 5 sessions, 10 sessions and 15 sessions of CBR in small, medium and large scenarios respectively. However, data rate is kept constant as we are trying to find the optimal set of parameters. This set of parameters help AOMDV to find and maintain the routes from source to destination.

Table 2. Simulation Parameters for VANET.

Parameters	Values		
	Small Map	Medium Map	Large Map
Simulation time	3 Minutes	3 Minutes	3 Minutes
Simulation area	560X447 m ²	873X790 m ²	1068X1075 m ²
Number of vehicles	10 Vehicles	20 Vehicles	30 Vehicles
Vehicle speed	0-50 km/hr	0-50 km/hr	0-50 km/hr
Propagation model	Two Ray Ground	Two Ray Ground	Two Ray Ground
Radio frequency	2.47GHz	2.47GHz	2.47GHz
Channel bandwidth	2Mbps	2Mbps	2Mbps
Mac protocol	Mac/802_11	Mac/802_11	Mac/802_11
Transmission range of vehicles	250m	250m	250m
CBR data flow	5 Sessions	10 Sessions	15 Sessions

5. Experimental Setup and mapping of problem

We have implemented PSO algorithm in C++. Further, the C++ code of PSO is integrated with ns-2 by using shell programming. It is important as the population generated by PSO is passed in ns-2 for experimentation. This process illustrated in Fig 1. In the experiments, we have taken three VANET scenarios small, medium and large. These scenarios are defined according to the size of the map and number of vehicles running over. The small, medium and large maps contain 10, 20 and 30 vehicles, respectively.

5.1. Problem Mapping in to PSO

PSO Algorithm⁸.

Input: 10 sets of 9 parameters value.

Output: optimized 10 sets of 9 parameters value.

Begin:

1. Initialize a population array of particles with random positions and velocities on D dimensions in the search space.
2. loop
3. For each particle, evaluate the desired optimization fitness function in D variables.
4. Compare particle's fitness evaluation with its $pbest_i$. If current value is better than $pbest_i$, then set $pbest_i$ equal to the current value, and p_i equal to the current location x_i in the D-dimensional space.
5. Identify the particle in the neighbourhood with the best success so far, and assign its index to the variable g .
6. Change the velocity and position of the particle according to the equations in 2 and 3.
 - a. $v_i = v_i + U(0, \phi_1) \otimes (p_i - x_i) + U(0, \phi_2) \otimes (p_g - x_i)$ (2)
 - b. $x_i = x_i + v_i$ (3)
7. If a criterion is met, exit loop
8. end loop

end

Steps of the PSO algorithm are explained below according to the problem mapped.

1. The population (x_i) is initialized as 10 sets (Random sets) of 9 parameters value as input. Here, the search dimension is 9 parameters. Where $i=1, 2, 3 \dots 10$.
2. This step is a loop which constitutes steps 3 to 7.
3. The fitness function value of 10 sets (x_i) is evaluated by ns-2 in the form of communication cost (c_i) as mentioned in Fig.1. Where $i=1, 2, 3 \dots 10$.
4. In first generation, the $pbest_i$ and p_i are set equal to communication cost (c_i) and x_i respectively. The x_i denotes current position of i^{th} set in 9-dimension search space. For successive generations the fitness value c_i for x_i is compared with $pbest_i$. If c_i is better than $pbest_i$, then set $pbest_i$ equal to c_i and p_i equal to the current location x_i in the 9-dimensional space. Where $i=1, 2, 3 \dots 10$.
5. The value of i corresponding to minimum $pbest_i$ is selected and assigned to g . Where i belongs to 1 to 10.

6. The initial velocity for first generation is set to zero. The successive velocity and position are calculated according to equation 2 and 3 respectively. The value of ϕ_1 and ϕ_2 is set equal to 2. The symbol \otimes denotes component wise multiplication. $U(0, \phi_k)$ represent a random number between 0 and ϕ_k , where $k=1,2$.
7. Here, condition is checked to terminate the loop after evaluating 50 successive generations.
8. The loop terminates after successful evaluation of 50 generations.

5.2. Result Analysis

The above experiment is conducted for 10 different simulation runs (for 10 different seed values) for the population size of 10, on each map size. From this experimentation, we get a final value of parameters for which communication cost is evaluated. A significant amount of drop in communication cost is observed. The communication cost for default value of parameters as well as for an optimized value of parameters is shown in Table 4 and Fig 3 respectively.

Table 3. Default and Optimized Parameters value.

Parameters	A_R_T	A_L_H	M_R_T	N_T_T	R_R	T_S	T_I	T_T	N_D
Default	3	2	6	0.04	2	1	2	7	35
Optimized for small map	9	1	10	0.89	10	10	10	1	2
Optimized for medium map	3	1	10	0.4	1	10	10	2	1
Optimized for large map	10	1	10	0.4	10	10	10	1	1
A_R_T=ACTIVE_ROUTE_TIMEOUT					A_L_H=ALLOWED_HELLO_LOSS				
M_R_T=MY_ROUTE_TIMEOUT					N_T_T=NODE_TRAVERSAL_TIME				
R_R=RREQ_RETRIES					T_S=TTL_START				
T_I=TTL_INCREMENT					T_T=TTL_THRESHOLD				
N_D=NETWORK_DIAMETER									

Table 4. Communication Cost.

Map	Communication Cost	
	Default	Optimized
Small Map	-0.053130	-0.119750
Medium Map	0.510642	0.103417
Large Map	0.743864	0.332984

Table 5. PDR

Map	PDR	
	Default	Optimized
Small Map	0.836450	0.872820
Medium Map	0.421921	0.429355
Large Map	0.269531	0.237165

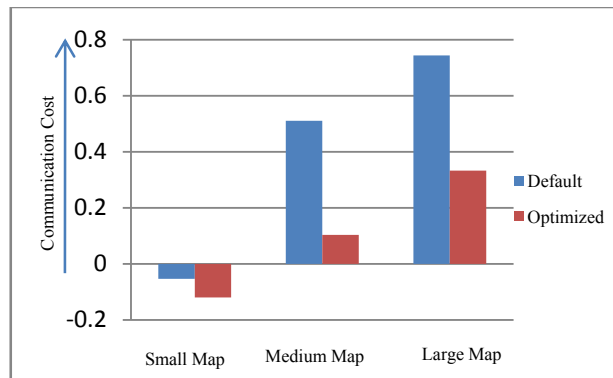


Fig. 3. Communication Cost (Chart Representation).

The default and optimized value of parameters obtained from PSO corresponding to each scenario are given in Table 3. The communication cost for small, medium and large map, has dropped by 125.38%, 79.75% and 55.24%, respectively. These drops in communication cost are very significant in the VANET. The relative change in each QoS metric for small, medium and large map are shown in Table 5, Table 6 and Table 7 respectively. From Table 5, it can be seen that PDR for small and medium map have increased slightly, but for large map, there is little drop in it. From Table 6 and 7, it can be observed that AE2ED and NRL in all scenarios have dropped significantly. For checking the convergence of our modified algorithm for PSO, we have executed the algorithm 10 times over same set of randomly generated input with different seed values for each map. The standard deviation of the 10 different optimized communication costs generated for small, medium and large map comes out as 23.14%, 25.05% and 16.8%

respectively. The average of AE2ED for small, medium and large map size is 80.65%. (drop). Similarly, average of NRL and PDR for small, medium and large map size is 37.05% (drop) and 1.96% (drop) respectively. The algorithm shows drastic improvement in the performance of AOMDV for the given scenario.

Table 6. AE2ED. Table 7. NRL.

Map	AE2ED	
	Default	Optimized
Small Map	0.099540	0.049100
Medium Map	0.310955	0.013162
Large Map	0.25112	0.011282

Map	NRL	
	Default	Optimized
Small Map	1.676160	1.509630
Medium Map	3.141581	1.570726
Large Map	4.016465	2.240912

6. Conclusion and Future Work

The performance of most of the routing protocols critically depends on their parameters value and there is large number of combination of parameters value having combinatorial nature. It is impractical to find optimal combination of parameters value by testing each combination in given scenario of VANET. In this paper, therefore, an algorithm based on PSO (a metaheuristics) is implemented and tested on real map scenario to obtain the optimal value of parameters in AOMDV. The obtained value of parameters shows drastic improvement in QoS compared to the default value of parameters. There is 80.65%, 37.05% and 1.96% drop in AE2ED, NRL and PDR respectively. Only problem with the approach is in the large map, there is drop in PDR but overall performance is significant. For better QoS in a given scenario the configuration of routing protocol is very important and this configuration can be obtained by using metaheuristics because of being large number of combination. In future work, therefore, we will make an attempt to use other metaheuristics to optimize UDP, DSR and different other protocols.

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