Intelligent QoS routing algorithm based on improved AODV protocol for Ad Hoc networks

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Abstract. Mobile Ad Hoc Networks were playing an increasingly important part in disaster reliefs, military battlefields and scientific explorations. However, networks routing difficulties are more and more outstanding due to inherent structures. This paper proposed an improved cuckoo searching-based Ad hoc On-Demand Distance Vector Routing protocol (CSAODV). It elaborately designs the calculation methods of optimal routing algorithm used by protocol and transmission mechanism of communication-package. In calculation of optimal routing algorithm by CS Algorithm, by increasing QoS constraint, the found optimal routing algorithm can conform to the requirements of specified bandwidth and time delay, and a certain balance can be obtained among computation spending, bandwidth and time delay. Take advantage of NS2 simulation software to take performance test on protocol in three circumstances and validate the feasibility and validity of CSAODV protocol. In results, CSAODV routing protocol is more adapt to the change of network topological structure than AODV protocol, which improves package delivery fraction of protocol effectively, reduce the transmission time delay of network, reduce the extra burden to network brought by controlling information, and improve the routing efficiency of network.

1. Introduction
Mobile Ad Hoc Networks has self-organizing abilities to dynamically adapt to the changing environments such as in disaster reliefs, military battlefields and scientific explorations. With the continuous expansion of Ad Hoc network application range, more and more people raise different requirements in bandwidth, time delay, computation spending and other aspects. Therefore, as for the specific business requirements, at the same time of providing routing function, Ad Hoc also guarantees to meet with requirements of a certain service quality. However, due to the changing dynamic network structure of Ad Hoc network, it is a really changeling task to offer communication service which meets some certain service quality requirements [1].

In the process of specific application, in order to adapt to different environment, node in Ad Hoc is in moving state at any time, therefore frequent link chain scission and network disconnection can be caused. The current networking protocol can’t adapt to this change very well which greatly influences the circulation of network data. Moreover, the continuous expansion of Ad Hoc network application range requires Ad Hoc to retain its advantages, and also guarantee the communication quality of network such as safety requirement and real time requirement. To solve those problems, the key point is that Ad Hoc network should support QoS [2], that is, guarantee that the data transmission of
network should conform to a certain requirements of computation spending, bandwidth, time delay and others. The basic method of Ad Hoc network supporting QoS is to provide QoS guarantee system [3], in which, the most core technique is to find a path with enough resources. Because of the dynamic network system, Ad Hoc makes itself different from other normal fixed network. The traditional methods are not unfit for solving QoS problem of Ad Hoc, therefore, new methods should be worked out to make Ad Hoc network satisfy with the requirements of communication quality. To seek for a path which confirms with QoS requirements in the changing topological structure of Ad Hoc network is a multi-constrained NP problem [4]. An effective method of solving multi-constrained NP problem is to find a solution by CS Algorithm [5].

Routing protocol based on QoS is the hot spot of the current research, but the obtained symbolic achievements are not many. Those routing mechanisms brought forward by people are mostly in the phase of theoretical research and hardly can be applied in actual world. To sum up the research thoughts, we can conclude that their routing designs with QoS constraint can start from two directions: (1) improve the traditional routing protocol. The main idea of this thought is to consider QoS constraint in the process of calculating optimal routing algorithm, rather than only take minimum hop as reference. The specific performance in table driven formula routing protocol is to add the information of QoS parameter to routing information which exchange among nodes, the options of optimal-path carry out among originating node; in on-demand routing protocol, QoS constraint is only needed to add in the discovering process of routing, so that the found path can satisfy with the business requirements [6].

2) Design new-pattern routing according to QoS constraint condition. This design thought takes advantage of various routing strategies to realize QoS guarantee. In an ad hoc network, all communication is done over wireless media, typically by radio through the air, without the help of wired base stations. Since direct communication is allowed only between adjacent nodes, distant nodes communicate over multiple hops. The quality-of-service (QoS) routing in an ad hoc network is difficult because the network topology may change constantly, and the available state information for routing is inherently imprecise. In [7], it proposed a distributed QoS routing scheme that selects a network path with sufficient resources to satisfy a certain delay (or bandwidth) requirement in a dynamic multihop mobile environment. The proposed algorithms work with imprecise state information. Multiple paths are searched in parallel to find the most qualified one. Fault-tolerance techniques are brought in for the maintenance of the routing paths when the nodes move, join, or leave the network. In [8], the existing location-based routing approaches, such as flooding-based routing schemes and localized routing schemes, have their limitations. Motivated by ticket-based routing, we propose an on-demand location-aided, ticket-based QoS routing protocol (LTBR). Two special cases of LTBR, LTBR-1 and LTBR-2, are discussed in detail. LTBR-1 uses a single ticket to find a route satisfying a given QoS constraint. LTBR-2 uses multiple tickets to search valid routes in a limited area. All tickets are guided via both location and QoS information. LTBR has lower overhead compared with the original ticket-based routing, because it does not rely on an underlying routing table. On the other hand, LTBR can find routes with better QoS qualities than traditional location-based protocols. In [9], a core-extraction distributed ad hoc routing algorithm for quality-of-service (QoS) routing in ad hoc network environments, CEDAR has three key components: (a) the establishment and maintenance of a self-organizing routing infrastructure called the core for performing route computations; (b) the propagation of the link-state of high bandwidth and stable links in the core through increase/decrease waves; and (c) a QoS-route computation algorithm that is executed at the core nodes using only locally available state. However, this algorithm exist the following defect: the performance of the whole network depends on the division of core regions to a large extent. If the division is inappropriate, the network performance shall be damaged severely, therefore, meticulous core region division of algorithm and maintaining algorithm are necessary.

With the deep research of Ad Hoc On-Demand Distance Vector Routing, facing with the fixed defect of network, people come up with various optimized improvement programs. Starting from the basic function of On-Demand Distance Vector Routing protocol, the ultimate purpose of those
Improvement methods is reduce time delay and computation spending, and guarantee delivery rate. To achieve this purpose, more information about network state needs to be collected. Moreover, we should discard the dross and select the essence in the process of information transmission, adjust the transmission behaviour according to the current state, reduce the circulation of unnecessary information as much as possible and reduce the network burden. Therefore, self-adaptive design method is a good choice. Swarm intelligence [6] is a kind of bionic intelligence based on assembling cooperative behaviours of simple individual, and can work out complicated distributed problem flexibly. Moreover, it doesn’t need being controlled by centre in solving procedure. It only involves some basic mathematic operation and has less constraints of solving problems, therefore, swarm intelligence heuristic routing method is one of ideal solutions for solving Ad Hoc On-Demand Distance Vector Routing problems.

In CS algorithm, though preferential random walks components are beneficial to increase the diversity of species and strengthen the global searching ability of algorithm, as for multidimensional objective functions and solution uses overall update evaluation strategy, it shall influence the convergence rate of algorithm and the quality of solution. The routing protocol research of ant colony algorithm has been mature, but as for routing of such protocol, the parameter controlling process carried out for realizing information exchange is complicated, and the actual operation is much more complex. However, the iterative process mechanism of CS Algorithm is simple, has less parameters and controllable process, therefore in this essay, research is mainly based on Ad Hoc On-Demand Distance Vector Routing protocol of CS Algorithm. To solve the optimization problem of On-Demand Distance Vector Routing with CS Algorithm is a currently new application area. How to take advantage of CS Algorithm self-adaptive distributed optimization characteristic, integrate the abilities of clustering collaboration and multi-objective optimization into solving the routing problems as required, need to fully consider the feasibility and designing difficulty of On-Demand routing protocol technique based on CS Algorithm.

Ad Hoc On-Demand Distance Vector Routing protocol (CSAODV) based on CS Algorithm directs at AODV protocol, with main purpose of getting improvement through AODV protocol routing detecting process and routing calculation strategy, considering bandwidth, consumption and time delay comprehensively when seeking for optimal-path, and further improving the service quality of network. CSAODV protocol obey with the structure of Ad Hoc On-Demand Distance Vector Routing protocol, and comprise of routing detection, routing maintenance and repairing mechanism [10]. Of which, in routing detection, the calculation of optimal-path is completed by improved-CS Algorithm. CS Algorithm is executed in objective node, take bandwidth, time delay and computation spending as optimization objective. The information collecting of bandwidth, time delay and computation spending goes through the whole process of routing detection. The detected network state information in the process of routing detection is all included in routing request package. When objective node collects a certain number of routing packages, according to the detected network state information, it can construct topological structure which reflects the current network state and select one optima-path as per the topological structure to reach a balance among computation spending, bandwidth and time delay. In the process of routing exploration, the routing package submitted by originating node records the information of bandwidth and time delay which passes through node in network transmission, and stores all nodes according to the order of passing through. After the intermediate node receiving routing package, determine whether transmit this package according to ID of request package. This strategy can effectively avoid the production of routing loop. In routing maintenance and repairing mechanism, all intermediate nodes send HELLO package to the former hop and latter hop in stored path periodically and the processing strategy can be determined according to whether reply package can be received in regulated time. As for choosing package transmission path, CSAODV protocol resorts to the same data transmission mechanism as AODV protocol, that is, the current node which has received package only need to know the next hop to the objective nod, instead of storing all nodes in path which package has passed through.
2. Cuckoo Search algorithm

Cuckoo takes a special reproduction strategy of parasitic brooding. She deposits her eggs in other birds’ nests in order to make other birds hatch the next generation for her. To reduce the probability of being discovered, some cuckoos shall make up her eggs like those of the selected birds. When other birds find alien eggs in their nests, they will abandon those eggs or put them in their own nests, or build a new nest in other places. Based on the reproduction strategy of cuckoo, Yang and Deb draw out CS-Algorithm which is based on three ideal rules [6]:

Rule 1. Each cuckoo only produces 1 egg for one time, and randomly chooses one bird nest for storage. Rule 2. The bird nest with the best egg shall be reserved for the next generation. Rule 3. The number of available bird nests are fixed, and the probability of being discovered to be the alien eggs is $P_a \in [0, 1]$.

Based on the above three rules, the basic procedure of CS algorithm is as shown in algorithm 1.

Algorithm 1. Cuckoo Search.

Begin
Initialize the population: n host nests $X_i (i=1,2,...,n)$;
Calculate the fitness value: $F_i (i=1,2,...,n)$.
While (doesn’t meet the stop condition)
Take the new solution $X_i$ generated by Lévy flight;
Calculate the fitness value $F_i$ of the new solution $X_i$;
Choose candidate solution $X_i$;
If ($F_i > X_i$)
Replace candidate solution with the new solution;
End
Discard the bad solutions according to the detection probability $P_a$;
Replace the discarded solution with the new solution generated by preferential random walks
Reserve the best solutions.
End
End

In CS algorithm, one bird nest represent one candidate solution. Firstly, CS algorithm generates a new solution in Lévy flights random walk way based on current solution, evaluates and reserves better solutions; secondly, discard some solutions according to detection probability $P_a$; Lastly, regenerates a new solution with the same number as that of the discarded solutions by preferential random walks, complete one-iteration after evaluation and reserving the better solutions.

When takes the new solution $X_i$ generated by Lévy flights random walk, execute the operation of formula (1):

$$X_{g+1,i} = X_{g,i} + \alpha \odot \text{Lévy}(\beta)$$

Thereinto, $X_{g,i}$ represents the i solution of the g generation; $\alpha$ is step message, used for controlling the range of random searching. In order to gain more useful step messages from the current optimal solutions, reference [8] resorts to formula (2) to calculate step message:

$$\alpha = \alpha_0 (X_{g,i} - X_{\text{best}})$$

Thereinto, $\alpha_0$ is constant ($\alpha_0 = 0.01$), $X_{\text{best}}$ represents the current optimal solution.

In Formula (1), $\odot$ is entry-wise multiplications, $\text{Lévy}(\lambda)$ obey Lévy probability distribution:

$$\text{Lévy}(\beta) \sim u \frac{\phi u}{v^{\frac{1}{\beta}}}$$

For easy calculation, reference [6] resorts to formula (4) to calculate Lévy random number:

$$\text{Lévy}(\beta) \sim u \frac{\phi u}{v^{\frac{1}{\beta}}}$$

Thereinto, $u, v$ obey standard normal distribution, $\beta = 1.5$. 

Obviously, synthesize formula(1) ~formula(5), in Lévy flights random walk components, CS algorithm takes formula(6) to generate the new solution $X_i$:

$$\phi = \left( \frac{\Gamma(1+\beta) \times \sin\left(\frac{\pi}{\beta} \right)}{\Gamma\left(\frac{1+\beta}{\beta}\right) \times \beta} \right)^{-\beta}$$  \hspace{5cm} (5)

$$X_{g+1,i} = X_{g,i} + \varphi \times u \frac{X_{g,i} - X_{g,best}}{\delta} \right)$$  \hspace{5cm} (6)

After discarding some solutions according to a certain probability (detection probability), algorithm takes preferential random walks to regenerate the new solutions with the same number, see formula(7):

$$X_{g+1,i} = X_{g,i} + r \times (X_{g,j} - X_{g,k})$$  \hspace{5cm} (7)

Thereinto, $r$ is zoom factor, a uniform random number in $(0,1)$ section; $X_{g,j}$ and $X_{g,k}$ are two random solutions of the g generation.

3. Routing Detection Strategy of CSAODV protocol

The production of routing request information

When originating node is going to send a package, firstly check if any routing reached objective exists in the current routing table; if exist, send the date directly; if not, cache data and then start routing detection mechanism, and broadcast routing request package RREQ. When originating node has sent the first RREQ package, it shall start a timer and expect to receive RREP sent by objective node before time expiring. If receives RREP package in specified time, get out the data from cache memory and send it; if not, originate the routing request.

3.1. The broadcast and controlling of routing request information

To avoid the unnecessary broadcasting of routing request information in the whole network, the originating node shall expand the searching scope gradually. In searching with bigger and bigger scope, originating node shall set TTL value in IP head of RREQ package as TTL_START, the waiting time of RREP as RING_TRAVERSAL_TIME. If RREP waiting-time out after sending out RREQ, the originating node shall broadcast RREQ again, and TTL value shall be added to TTL_INCREMENT, which shall last until TTL value in RREQ package reaches the pre-set threshold value TTL_THRESHOLD. When reaching the threshold value, TTL shall be set as NET_DIAMENTE each time, the expiration time of waiting RREP is fixed RING_TRACERSAL_TIME. If each routing seeking is carried out in Ad Hoc network scope, TTL_START and TTL_INCREMENT shall set as NET_DIAMETER to reach the objective.

3.2. The processing and transmission of routing request information

When node receiving a RREQ group, it should firstly check whether the originating node of RREQ routing request package is this node, if it is, discard this package, otherwise, check if this RREQ package is received before. If such RREQ group has been indeed received before, this node shall be discarded to this RREQ group, if not, determine if it is the objective node of this RREQ group. If this current node isn’t the objective node in this RREQ group, transmit this RREQ directly, that is to broadcast RREQ package to all neighbouring nodes. Before broadcasting, calculate the time delay between the current node and the last node, the calculation method is the timestamp of receiving RREQ package minus the timestamp of the last node sending this RREQ, and then fill this time delay into the according position in RREQ package time delay list which shall be transmitted. Except time delay, the currently available bandwidth of node shall be added to the bandwidth list. At last, update the list for nodes which are passed through by RREQ package, add other information required by transmitting communication-package, and then transmit to RREQ package.

When the first routing request package reaches objective node, objective node shall initiate a timer to cache all routing request package before the time expiring. After the time expiring, objective node extract the received path lists and according bandwidth and time delay information in all RREQ
groups, and construct topological structure which reflects the current network state. This topological structure includes time delay and bandwidth information of chain. Afterwards, take advantage of network topology constructed by improved-CS Algorithm to find a path with minimum computation spending, the most adequate bandwidth, and minimum time delay. In the operation process of algorithm, each bird nest represent a path between originating node and objective node, the fitness function of determining the superior and inferior of the bird nest as follows:

\[
F(r_{s,d}) = \frac{1}{C(r_{s,d})} \left( \prod_{e \in r_{s,d}} \varphi(D(e) - \Delta) + \varphi(B(r_{s,d}) - \delta) \right)
\]

Of which, \(r_{s,d}\) is a routing between originating node and objecting node, \(C(r_{s,d})\) is computation spending of routing sdr. \(D(e)\) is time delay in chain \(e\) which is included in routing \(r_{s,d}\), \(B(r_{s,d})\) is the minimum bandwidth in routing \(r_{s,d}\). \(\varphi(\cdot)\) is penalty function, when bird nest satisfies with the constraint condition, its value is 1, otherwise, it equals \(r, r \in (0,1)\) the extent of penalty. The higher the fitness value of bird nest is, the better the found path performance is. At last, choose the path of bird nest with the highest fitness value as optimal-path. After selecting the optimal-path, objective node constructs routing reply package RREP, fill the optimal-path which is found by CS ALGORITHM into the corresponding area, and then transmit RREP package to the node before reaching objective node in optimal-path.

3.3. Receiving and forwarding routing responses

RREP package returns to RREQ originating node along the reverse direction of the selected optimal-path. After the intermediate node receiving the first RREP package, it shall reach the forward routing of RREQ objective node and backward routing of RREQ originating node according to the record of optimal routing algorithm in RREP before transmitting, and store bandwidth and time delay in responding routing table, and then transmit RREP package to the last node of the current node in optimal-path.

3.4. The processing after originating node receiving the reply information

After originating node receiving the reply package, according to the path information in RREQ package, update the current routing table, extract data from cache memory and sent it out immediately. The flow chart of CSAODV protocol routing detection is shown in Figure 1.

4. Package Transmission Strategy in CSAODV protocol

CSAODV protocol uses forward routing to transmit package. In note routing table, there stores the address of the next hop of reaching objective node and corresponding bandwidth, time delay. When intermediate node receiving the package sent by originating node, it needs to check if any routing has reached objective node in routing table, if exist and bandwidth and time delay conforms to the requirement of package in this routing table, transmit this package to the next hop node in this routing table; if not, initiate routing repairing mechanism.

Originating node receives RREP package sent by objective node means a path which conforms to QoS constraints between originating node and objective node has constructed. At the same time of originating node initiating data transmission, all nodes in this path begin to initiate routing maintenance mechanism. In the expiry date of this path, all nodes in this routing should send HELLO package to the former hop and latter hop nodes periodically and expect to receive the reply of node in regulated time. If no reply is received in regulated time, it shows that chain scission occurs between two nodes, and then initiate routing repairing mechanism.

CSAODV protocol routing repairing, if chain scission occurs between the next hop and this node in routing, check if other path to reach the next node for this node exist; if exist and bandwidth and time delay in path are within the required scope, the next hop can be reached through this node; if not, detect whether any path with conforming bandwidth and time delay exist for this node reaching
objective node, if exist, transmit package along this path. If these two paths don’t exist, inform that originating node and objective node can’t be reached, afterwards originating node initiate a new round of routing detection.

CSAODV protocol and AODV protocol are all Ad Hoc On-Demand Distance Vector Routing protocols. CSAODV protocol is based on AODV protocol. Both of them adapt to On-Demand Distance Vector Routing-network equivalent to node function, and used for data transmission of single objective node. The similarity lies in the basically same routing mechanism used by them, the major difference is the different strategy selected by optimal routing algorithm. AODV protocol updates routing table according to the serial number and the number of hops in RREP package. In AODV protocol, the routing table of node includes the known routing of nodes which has reached the objectives.

When originating node receiving a RREP package, extract the serial number and the number of hops, and compare those two with the corresponding routing items in current routing table. If the serial number of the new package is bigger than the serial number in routing item, then the path represented by the newly received RREP package is the transmission path, update the corresponding routing items; if these two serial numbers equal each other, compare the number of hops, and choose the path with

![Flow chart of CSAODV protocol routing detection](image-url)

**Figure 1. The flow chart of CSAODV protocol routing detection**
less hops as the transmission path; if the serial number of the newly received RREP package is smaller than the existed serial number in the routing table, then no action and discard RREP package directly. When originating node receiving each RREP package, it will repeat the above procedures. If choose the path represented by RREP package as transmission path, update the corresponding routing items, the following package shall send out the new routing table. CSAODV protocol gets optimal-path by CS ALGORITHM calculation. When choosing optimal-path, comprehensive consider computation spending, bandwidth and time delay, and the optimization process is completed by objective node. First, collect time delay and bandwidth information in path exploration process, and store the order of nodes passed through by RREQ package. When RREQ reaching objective node, the objective node doesn’t reply to RREQ package immediately, but initiate a timer to receive all RREQ package before the timer expiring. After the timer expiring, reflect the information of current network state according to the received RREQ package, construct the network topological-structure, and take advantage of CS algorithm to select the most balanced routing among computation spending, bandwidth and time delay as the final routing. Compare the two routings to choose mechanism, CSAODV protocol is added to computation spending, bandwidth and time delay index, then select a routing with certain QoS guarantee, making network more reliable and real-time in data transmission.

5. Simulation
To measure the performance of routing process in CSAODV protocol, this paper chooses AODV protocol before improvement as reference, and designs three network environments to compare packet delivery fraction, time delay and routing spending of CSAODV protocol and AODV protocol in different network environment. To avoid the influence on simulation result from random factors, the simulation of each scene shall repeat five times and then take the average value as the simulation result. To evaluate the performance of CSAODV protocol, this paper carries out simulation test in Window XP+sygwin+NS2-2.8, and compares with AODV protocol in the same setting environment, network environment and state characteristics. The simulation environment set as: simulation area is 1500m*300m, the number of nodes is 10~100, node mobility model is random walk mobility model, the speed of node is 0~30m/s, the protocol type of MAC layer is IEEE802.11, node communicate scope is 250m, bandwidth is 2Mb/s, transmission layer is protocol UDP, data flow CBR, the packet transmitting speed is 4 per second, the data packet capacity is 512bytes, simulation time is 500s. In random walks mobility model, each node is a single individual, the travelling speed of current position of node and objective position is random, its value may be a random value from 0 to the maximum travelling speed. After node reaching an objective position, it will remain for a short while, then select a coordinate in simulation area as the next objective position and move towards the objective position with a constant speed. Node runs repeatedly this process until the simulation ends.

To perform the simulation of routing protocol, evaluate such major indexes of routing protocol as follows: Packet delivery fraction: compare the package received successfully by network application layer and all packages. Packet delivery fraction is the major index of evaluating routing, if it is 1, all packages reach the objective node, which is the best ideal state; if it is 0, which means all packages shall be discarded without reaching objective node, which is the worst ideal state. According to the characteristics of Ad Hoc-network, packet delivery fraction will not less than one appropriate value in different circumstances. How to increase packet delivery fraction as much as possible is the most question for each routing protocol to take account into, and also the ability to exhibit how routing protocol takes advantage of the current network’s QoS index.

End-to-End time delay: Within the total simulation time, seek for and maintain the average time of message transmission from originating node to objective node in routing path. End-to-End time delay shows the reaction ability of routing protocol, and a kind of index for users to evaluate routing protocol.

Routing expense: in total simulation time, for data transmission, the ratio of the total number of routing controlling message and the number of data message can be shown by percentage.
5.1. The influence on protocol performance of network scale

To compare the adaptive abilities of two protocols to different scaled network, increase the number of network nodes gradually in this simulation. From Table 1, we can see that, with the increasing number of network nodes, the delivery fractions of the two protocols have different growth, but the delivery fraction of CSAODV protocol is always higher than AODV. This is because that with the increasing number of network nodes, the connection probability between two nodes increases accordingly, which makes the selectable number of routing between originating node and objective node increases, the packet delivery fraction increases as well. CSAODV considers the influence of bandwidth factor when routing, the stability of chain is favourable, and therefore packet delivery fraction is always in higher state. Table 1 reflects the changing situation of end-to-end time delay in two protocols when network scale changes, CSAODV protocol has less influence and shorter network time delay in all scales. This is because that CSAODV protocol considers the time delay factor in QoS constraint, and chooses the path with shorter time delay in data transmission, the more network nodes, the bigger the probability of paths with shorter time delay is.

| Grouped Delivery Rate | Time Delay (s) | Routing Spending |
|-----------------------|----------------|------------------|
| CSADOV | AODV | CSADOV | AODV | CSADOV | AODV |
| 10 | 0.928 | 0.914 | 0.063 | 0.070 | 0.19 | 0.20 |
| 20 | 0.934 | 0.921 | 0.058 | 0.063 | 0.21 | 0.24 |
| 30 | 0.937 | 0.923 | 0.057 | 0.061 | 0.22 | 0.25 |
| 40 | 0.941 | 0.927 | 0.055 | 0.059 | 0.23 | 0.25 |
| 50 | 0.941 | 0.930 | 0.049 | 0.056 | 0.23 | 0.25 |
| 60 | 0.942 | 0.932 | 0.041 | 0.051 | 0.24 | 0.27 |
| 70 | 0.944 | 0.935 | 0.041 | 0.045 | 0.25 | 0.29 |
| 80 | 0.947 | 0.937 | 0.042 | 0.042 | 0.25 | 0.31 |
| 90 | 0.956 | 0.937 | 0.034 | 0.041 | 0.36 | 0.32 |
| 100 | 0.965 | 0.939 | 0.029 | 0.041 | 0.27 | 0.34 |

| Grouped Delivery Rate | Time Delay (s) | Routing Spending |
|-----------------------|----------------|------------------|
| CSADOV | AODV | CSADOV | AODV | CSADOV | AODV |
| 0 | 1 | 1 | 0.024 | 0.038 | 0.25 | 0.29 |
| 5m/s | 0.965 | 0.939 | 0.029 | 0.041 | 0.27 | 0.34 |
| 10m/s | 0.951 | 0.937 | 0.035 | 0.044 | 0.31 | 0.39 |
| 15m/s | 0.947 | 0.918 | 0.039 | 0.056 | 0.40 | 0.50 |
| 20m/s | 0.922 | 0.872 | 0.046 | 0.062 | 0.39 | 0.52 |
| 25m/s | 0.901 | 0.855 | 0.050 | 0.070 | 0.50 | 0.59 |
| 30m/s | 0.882 | 0.783 | 0.064 | 0.081 | 0.58 | 0.66 |
With the increasing network scale, the connection probability of nodes increases and the network topology becomes complicated; therefore, network needs more controlling information in routing process. Table 1 is the influence on routing expenses affected by network scale. We can see that with the increasing network scale, the gap between CSAODV expense and AODV expense is more and more obvious, and the changing range of CSAODV protocol is small. This is because that stability and durability of the routing selected by CSAODV is higher than AODV, the message for processing chain scission is less, which lessen the proportion taken by controlling information in network flow.

5.2. The influence of moving speed on protocol performance

To compare the influence of network topology change on the two protocols, increase the speed of node continuously in this simulation, the specific experimental parameter settings can refer to the table. The moving speed of node is an important aspect of affecting Ad Hoc network performance, we can see from Table 2, the routing quality of network decrease continuously with the increasing moving speed of node. This is because that the rapid moving of node results in much more frequent change of network topological-structure, chain scission occurs among nodes beyond the communication range of each other, therefore, packet loss rate of network increases, end-to-end time delay increases, the information message for network to judge chain scission processing and controlling message of repairing routing increase accordingly. However, CSAODV protocol considers QoS factor when choosing routing, choose a path with bigger bandwidth for data transmission, which strengthen the reliability and stability of network transmitting data, and reduce influence brought by chain scission.

5.3. The influence of network load on protocol performance

To compare the performance of two protocols in different network load, increase the number of originating nodes gradually in this simulation, the specific experimental parameter settings is shown in the table

![Fig 2. Table 2. Routing performance comparison (Network scale node number: 100; Node movement speed: 5m/s)](attachment:image)
Figure 2(a) shows the influence of network load on packet delivery fraction, we can see that the packet delivery fraction of AODV protocol reduce greatly when network load increases, while the decreasing rapid of the packet delivery fraction in CSAODV protocol is relatively slow. That is because that with the increasing load on network, the probability of network congestion increases accordingly, while constraints are added to bandwidth when CSAODV protocol is routing, which makes packet transmit in routing with larger bandwidth, therefor guarantee the packet delivery fraction. Figure 2(b) shows that the end-to-end time delay of network increases with the increasing number of originating nodes. This is because that the increasing number of originating nodes shall increase the probability of congestion occurring, and further increases the transmission time delay of network. Compared with AODV protocol, because that constraint is added to time delay when CSAODV selects routing, its time delay performance gets less influence in the increasing process of network load. Figure 2(c) shows the comparison of routing expenses for tow protocols with different number of originating nodes. This is because that it doesn’t consider the network flow when routing based on the minimum hopping number. When the number of originating node increases, some nodes shall be selected frequently for routing, the probability of chain scission becomes bigger, therefore the controlling expenses for network to reselect routing shall increase accordingly. Because that bandwidth constraints are added to routing mechanism in CSAODV protocol, the node with better resources can be selected in priority, which to large extent reduce the probability of chain scission and reduce the proportion of controlling information for re-routing.

6. Conclusion
In different scaled network environment, except time delay, the routing quality of CSAODV and AODV protocol reduces with the increasing of scale, but CSAODV protocol is less affected. It is because of QoS system in CSAODV protocol which makes the selected routing relatively stable, and weakens the negative influence brought by the increasing number of nodes. In the environment in which node moving speed increases, though network performance will reduce obviously, the performance of CSAODV protocol is always superior to AODV protocol, which fully manifests the advantage of QoS guarantee to better adapt to the frequently changing network. In the network environment of node changing rapidly, the overall routing quality of network turns out descending trend with the increasing rapid, while the performance of CSAODV protocol is always superior to AODV protocol, which fully manifests the advantage of QoS guarantee to better adapt to the frequent changing of network. In network environment with different loads, CSAODV protocol comprehensively consider the influence of bandwidth and time delay on routing performance when CSAODV protocol is routing, which makes network flow distributed equally in the whole network and avoids bottleneck node in network due to local flow concentration. Overall, the performance of CSAODV protocol is superior to AODV protocol before improvement, and possesses a stronger adaptability and robustness in different-state network environment.

References
[1] Pierobon, M., Jornet, J. M., Akkari, N., Almasri, S., & Akyildiz, I. F. (2014). A routing framework for energy harvesting wireless nanosensor networks in the Terahertz Band. Wireless networks, 20(5), 1169-1183.
[2] Karaboga, D., Okdem, S., & Ozturk, C. (2012). Cluster based wireless sensor network routing using artificial bee colony algorithm. Wireless Networks, 18(7), 847-860.
[3] Lin, C. R., & Liu, J. S. (1999). QoS routing in ad hoc wireless networks. Selected Areas in Communications, IEEE Journal on, 17(8), 1426-1438.
[4] Wang, Z., & Crowcroft, J. (1996). Quality-of-service routing for supporting multimedia
applications. Selected Areas in Communications, IEEE Journal on, 14(7), 1228-1234.

[5] Camilo, T., Carreto, C., Silva, J. S., & Boavida, F. (2006). An energy-efficient ant-based routing algorithm for wireless sensor networks. In Ant Colony Optimization and Swarm Intelligence (pp. 49-59). Springer Berlin Heidelberg.

[6] Wang, J. S., Han, S., Shen, N. N., & Li, S. X. (2014). Features Extraction of Flotation Froth Images and BP Neural Network Soft-Sensor Model of Concentrate Grade Optimized by Shuffled Cuckoo Searching Algorithm. The Scientific World Journal, 2014.

[7] Chen, S., & Nahrstedt, K. (1999). Distributed quality-of-service routing in ad hoc networks. Selected Areas in Communications, IEEE Journal on, 17(8), 1488-1505.

[8] Huang, C., Dai, F., & Wu, J. (2004, August). On-demand location-aided QoS routing in ad hoc networks. In Parallel Processing, 2004. ICPP 2004. International Conference on (pp. 502-509). IEEE.

[9] Sivakumar, R., Sinha, P., & Bharghavan, V. (1999). CEDAR: a core-extraction distributed ad hoc routing algorithm. Selected Areas in Communications, IEEE Journal on, 17(8), 1454-1465.

[10] Jain, J., Gupta, R., & Bandhopadhyay, T. K. (2014). Scalability enhancement of AODV using local link repairing. International Journal of Electronics, 101(9), 1230-1243.