Self-organizing network model
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Abstract

In this paper, a kind of self-organizing network model, which provides a new kind of network model based on the swarm intelligence for the suppliers, was introduced. The document defines the problems of the existing network, as well as the characteristics of the next generation Internet NGI, illustrates the motivation of self-organizing network model. In this paper, a network architecture model based on a kind of swarm intelligence was introduced, the collection technical term was defined, network parameters in the network node, network behavior and the node stability depict portrait was described. The document describes the important factors such as the user needs under the self-organizing network model, the network satisfaction, the avail computing, the path and multicast tree evaluation, the mathematical models of the QoS routing optimization, small-world behavior and so on, which have a relationship with the self-organizing network QoS routing.
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1. Introduction

In this paper, a kind of self-organizing network model, which provides a new kind of network model based on the swarm intelligence for the suppliers, was introduced. To a certain extent it can be resolved the problems along with the expansion of the network size and dynamic-increase. The document defines the problems of the existing network, as well as the characteristics of the next generation Internet NGI, illustrates the motivation of self-organizing network model. In this paper, a network architecture model based on a kind of swarm intelligence was introduced, the collection technical term was defined, network parameters in the network node, network behavior and the node stability depict portrait was described. The document describes the important factors such as the user needs under the self-organizing network model, the network satisfaction, the avail computing, the path and multicast tree evaluation, the mathematical models of the QoS routing optimization, small-world behavior and so on, which have a relationship with the self-organizing network QoS routing.
2. Term

We have the following definition of the term, attention: out of the self-organizing network these terms maybe have other definitions, so our definition is not universal, only having specific meaning in this paper:

Router

The smart node witch has a characteristic of biological behavior and has the ability to transmit and process in the self-organizing network.

Link

Communication line which connects the smart node in the self-organizing network.

QoS

It specifies variety of performance of packet transmission in the network, it is descriptions to variety of performance, include operational reliability, delay, jitter, packet loss and throughput rates.

Delay

Include the link transmission delay and the delay from its upstream node in processing on the path and communication conversion delay.

Delay-Jitter

It means the Delay-Jitter from its upstream node in processing on the path.

Error Rate

Include the link transmission error rate and the error rate from its upstream node in processing on the path. Assume that the size of the error rate achieved by the business which uses the Link has nothing to do with the type of business, only have relations with the type of the link and the network state at that time.

Stability

Here we define the stability of the node to say the state how the nodes can maintain the same degree of stability, the nodes having
a higher stability should be focus on the consideration when the routing.

User demands

User demand is the requirements of the internet users on the QoS parameters of the communication line. As the state of the network is imprecise what make the user demands indefinite, so use a series of range to express.

Cost

It is the cost of resources from providing the network service by network providers.

Price

Price is the charge that the users pay for using the network resources.

Worldlet edge

With running of the routing algorithmic, the nodes in the network will gradually accumulate some of the path to the other nodes; here we called these path worldlet edges.
3. The motivation and the existent problems

As the growing of computer network and the increasing of dynamic network, there is a challenge to the existing network model and routing mechanism. The expanding of the network scale requires strong self-organizing and self-management capabilities. Dynamic network require a distributed and adaptive routing mechanism, which the node should not maintain the global network information. With the combination of various technologies, especially mobile, wireless and broadband internet access at home and in the company. Numerous mobile terminals, devices and sensors, make the Internet scale growth sustainably. At the same time, applications will be all over the body, around the individual, family, transport and broader. All of this has increased the time and space complexity of network topology, and complexity of the dynamic, but also increased network administrator and user’s burden. In order to alleviate the burden on users and administrators and enable them extricate from the complex network configuration, a self-organizing network need to be designed and developed, and as far as possible to minimize the involvement of members.

Self-organizing phenomenon is prevalent in our lives. In the natural world, fish have a good organization into a structure of the group around, the ants could find the shortest route to find food, and these are good examples of self-organizing behavior. In the act of self-organizing phenomena, all of the entities establish a organizational structure which does not need a coordination center. Instead, these entities interact directly and constantly changed reacting to the local environment.

Self-organizing is not just distributed localized control, it is a result of independent entities relationship, structure and function. In the self-organizing systems, simple entity’s acting in the micro-level can reach to the entire system’s complex acting. This phenomenon known as the "emerging."

Self-organizing system another important characteristic is the adaptation to system environment changing. In fact, these entities have been in a constant implicit way to adapt to changing. For example, the self-organizing system often re-restructuring as reaction triggering to the internal and external changing. By doing so, it towards a desired useful structure and avoid to other structures.

It will be robustness towards failure and damaging by combining the self-organizing inherent adaptive and distributed properties. The system dose not exist a single point of failure, and the system can repair and correct the damage without outside helping. Therefore,
self-organizing system will not be collapse suddenly; it just
downgraded slowly when it has problems.

Now, the complexity of the communications network has become an
increasingly serious problem, the latest progress of self-organizing
system indicated that it may be find some solution here. Self-
organizing network model is based on the building up characteristics
and behaviors of self-organizing. In this paper, we will introduce a
kind of network model based on characteristics and behaviors of self-
organizing.
4. Related issues

In the network environment, we need to solve the main problem is routing problem. With the continuous expansion of the size of the Internet, multimedia services and real-time services are emerging; the user’s requirement to the QoS rises continuously. Based on various performance parameters, the QoS routing is to focus on issues in any of the network model.

In the self-organizing network environment, the solution to the routing problem bases on the QoS is general use routing algorithm and Routing strategy based on Swarm Intelligence. Before we introduce specific self-organizing network model, we first introduce Swarm intelligence and QoS routing.

4.1. Swarm intelligence

Swarm intelligence refers to the number of simple individuals have to cooperate with each other through the complex characteristics of intelligent behavior. A significant mark which the concept of swarm Intelligence was formally put forward was in the E Bonabeau which was published by Oxford University in 1999 and a monograph named "Swarm Intelligence: From Natural to Artificial System" wrote by M Dorigo and other people.

The concept of swarm comes from the observations to a number of insects such as ants, bees, and others in the natural world. Only a single ant’s intelligence is not swarm, but a few ants coming together, they can handle the food what they encountered on the road together. If having a group of ants, they will be able to work together to build a strong and beautiful nest, to resist the risk together, to bring-up future generations. This swarm behavior which demonstrated by gregarious biology was known as the swarm intelligence.

In 1994, Millon as M M raised five basic principles that Smart intelligence should followed:

1. Proximity Principle: Swarm can carry out simple space and time;
2. Quality Principle, Swarm can be able to responds to the quality factor;
3. Principle of Diverse Response: The scope of the Swarm should not be too narrow;
4. Stability Principle: Swarm should not change their behavior when the environment changes;
5. Adaptability Principle: Swarm can change their behavior in due course when it doesn’t require too high price.

Swarm intelligence has following characteristics:

1. Control is distributed, there is no central control. Thus, it is better to adapt to the working state of current network environment. It is also robust, one or more individual failure can not affect to the solution of whole problems;

2. Each individual swarm can change the environment, this is a way of indirect communication between the individual, which called stigmergy. As Swarm intelligence can transmit information in a way of indirect communication. With the individual number increase, the communication overhead increases smaller. So the Swarm intelligence has a better scalability;

3. The ability and rules of individual in the Swarm intelligence are simple. So the realization of Swarm intelligence is convenient;

4. Swarm intelligence complex behavior is emerging from the interaction of simple individual. So, the swarm has the ability of self-organizing.

Internet as a loose network connects the world. The key technologies about the realization of world-wide connectivity are routing technology. In the current Internet, routing has been essentially out of the traditional centralized control of telecommunications networks with the meaning of self-organization. However, this self-organization is reflected in the router level. Router has a number of different routing protocols, which use different routing algorithm. In order to make network operate coordinately, routers need to exchange a large number of information about links and network status, then calculate and update routing table, it has poor scalability. Internet’s rapid growth makes the existing route scalability and robustness inadequate. In order to adapt to the new network applications, a new and effective routing algorithm with better scalability need.

At present, as the extending of network scale and increasing of network speed, simplifying the construction and management of network nodes has became the key factor of reducing network costs, increasing network utilization and enhancing network reliability.

Inspired by the entomological society, many non-smart simple individuals show intelligence through co-operation simple acts, produced a series of complex solution to the problem by simulating, that is Swarm Intelligence Technology. By applying Swarm
Intelligence to the network routing, finding the best routing through a certain co-ordination of network routing proxy created by network node, and increases network scalability, adaptability and robustness.

4.2. QoS routing

QoS specifies variety of performance of packet transmission in the network, it is descriptions to variety of performance, include Operational reliability, delay, jitter, packet loss and throughput rates.

With the continuous expansion of internet scale, emerging of multimedia services and real-time operations, the QoS need is improved unceasingly. The research of QoS is helpful to improve network efficiency and reduce network cost. QoS mechanisms can be adopted by the provider, according to the different users of the different QoS requirements, provides a wide range of differentiated services and enhance customer satisfaction and improve network provider earnings. So, QoS is need in Self-organizing network.

There is two ways to enhance QoS. One is node control; the other is the control of whole network or local network. As the route is directly related to network performance, QoS routing is a key technology to resolve QoS problems.

QoS routing main goal is to meet transmission path of QoS requirements, and ensures the efficient use of network resources.

QoS routing process involves two aspects as follows:

1. Choosing of Measurement parameters

Measurement parameter is an important parameter in the process of QoS routing. It has a direct bearing on the algorithm complexity. Measurement parameter is divided into three categories: Convexity parameters, additive parameters and multiplicative parameter.

2. Routing

In accordance with the parameters and network information, has found the way to guarantee QoS. How to choose the path and ensure service sending along the path needs to be considered in the routing.

Source routing algorithm and the concept are very simple, easy to implement and evaluate. Source node’s centralized calculation can avoid kinds of shortcomings of distributed calculation, such as
inconsistent data in each node may cause the deadlock and the loop. However, since each source node needs to collect and maintain the whole global state, the source routing has the following problems:

1. As the source routing needs link state interactive, the overhead of maintaining Global state is large.

2. Source node calculates a viable path by Global state, so the overhead of time and space is large.

3. The obsolescence of Global state source node maintained cause a great affection to routing performance.

Distributed Routing spreads calculations into all nodes, reduces the complexity of the calculations, and even some algorithm only require locale state, therefore it has good scalability. However, distributed processing is more complex, especially in the multi-QoS bound difficult to design a good heuristic. In addition, each node calculates a viable path depend on the local information independently, it may be cause loop since inconsistent information, which requires additional loop detection algorithm.

Hierarchical routing reduces the information nodes interacted and the computational complexity, has a good scalability. However, information gathered led to the loss of state, it cause a great negative affection to QoS routing.

Routing can be divided into two categories: unicast routing and multicast routing, the algorithm is divided into unicast routing and multicast routing algorithm.

In QoS routing there are two basic problems: optimization and performance bound.

The optimize problem is looking for corresponding QoS optimal path. Performance bound is looking for corresponding path greater than QoS (such as bandwidth) or less than QoS (such as delay), choosing a solution in the set of performance requirements. Optimization requires the optimal solution, performance bound only need a solution meet the demand.

QoS routing algorithm have the following characteristics:

1. Intelligent

   Generally use smart algorithm, such as neural networks, evolutionary computation, and other intelligent optimization.
2. Heuristic

   Particularly in the multi-constraint QoS routing, due to the complexity of the calculation is complete NP, require the heuristic algorithm.

3. Adaptive

   It can adapt the network changes automatically, make network load balancing and not to obstruct.

4. Deal with inaccurate information

   Including the cost of fuzzy, imprecise network information, layered routing when topology aggregation.

5. Fairness

   Equitably access, equitably share resources or account QoS.

6. Robustness

   It can re-routing or has an alternative path when linking failure.
5. Self-organizing network design model

5.1. Model one: The design attains the partial behavior rule of the overall situation attribute

We consider a design which has a network function with establishment of global characteristics, such as: a unique address or connection. A center of the solution is to introduce a special entity to be responsible for the establishment of global attributes (such as: an address server). However, self-organizing paradigm distribute the responsibilities to various independent entities: there is no single entity to "manage" the entire organization, but each of the entities contributes to a collective act. According to this model, we must design a localized rules of conduct, if the rules applied to all entities, will be able to automatically achieve the desired global attributes (or at least close to). The localization means that the entity only has a partial view of the network and only interacts with their neighbors.

If we are able to simplify the overall attributes which we are wanted into the local attributes, this method can do it. In Multi-hop wireless network the topology control is a good example which can be used to explain the concept. Here, the overall attributes which we are wanted is all of the global device connectivity, keep low power consumption and interference. The overall attributes can be mapped into a local attributes: If each node to maintain all of its k-nearest neighbor connections, where k depends on the specific parameters, such a network topology will be derived from a high possibility of link. In order to reach the local characteristics, each of the nodes should accordingly adjust its transmission power.

In general, most self-organizing systems base on the partial view and the local acts which are simplified. Some people might argue the localized algorithm can not achieve global optimization in one specific attributes, but only to provide a nearly optimal solution. However, the second-best sometimes may be not a shortcoming in the dynamic network. Here the best configuration changes frequently, so fast reaching a stable configuration is important.

Finally, attention local attributes also means that the change in the network only impact Local influence. On the other hand, the decision of the local may also bring in a state of conflict in the network. For example, using local address assignment, two nodes may have the same IP address. This discussion led us into the second self-organizing network design model: tolerance and dealing with not perfect coordination.
5.2. Develop the implicit coordination

In any kind of the communications system, nodes share resources such as bandwidth and address. In order to make access to these resources in effective and fair, nodes must be coordinated in some way. One solution is to avoid the conflicts and contradictions between nodes. For example, we can assign a channel to only one user in a communication or a stream to. This can be done through explicit coordination. This form of coordination is typically applied in the center of the system. For example: signaling channel and the central database of addresses in cellular telephone.

If the network is dynamic, asynchronous, the pre-conflict avoiding and explicit signaling may be a serious problem. There is way to tolerate conflict, if we can manage them in a including way, that is, if the conflict is localized, time-bound, or easy to detect and resolve, the conflict is acceptable. A well-known example is the CSMA / CD protocol in LAN. Another example is that the address repeated testing in ad hoc network; it abandoned the ideals of the globally unique address, but allocated to the local node a unique address, besides having a local detection and resolving the address conflict.

5.3. Minimize the status information of existence over a long period of time

The third design model has a relationship with the network state. Much of the network topology needs the long-term survival information which has relationship with the node, the equipment storage, and maintenance and network status. For example, in cellular networks each of the device stores a special network address, such as location, security database, language boxes and the Internet gateway. This information must be manually configured by users, some network administrators or managers. In addition, some information of physical storage needs to maintain a state of synchronization what means that some information is continually stored in a number of between the nodes and equipments. Routing tables and data security is a very good example. In a dynamic network environment maintain the continuity of this is very difficult, especially when the node disconnect very often. We always need some central entity to ensure that the state information is the newest.

In order to achieve a high level self-organization, we should minimize the number of the status information which existed over a long period of time. One way is to bring in discovery mechanism; nodes can be able to get the information of the network entities or services. There are two different discovery mechanisms: reaction and pre-determined model. In reaction model discovery mechanism, the
node send asking message through multicast or broadcast, if the entity which was looked for has received the information, it uses the form of unicast in response. In the pre-determined model discovery mechanism, the special entities take the initiative to send a message to announce their existence. If the node has received such information, they know the existence of the address and type of service and other information. Information maintains in this discovery mechanisms and it is regularly updated, but it dose not need to survive for a long time. Networks become having more adaptability and robustness. In addition, it decreases the assumption for other nodes, and removes the dependence between nodes.

5.4. Design the protocol of the orientation change

Another important aspect is the ability of the node what respond to on the network and environmental change, this is mainly because of largely the changes in the resource constraints, the changes of the user’s needs, the node remove or the node fail. Because there is no central entity to inform the other nodes on the change of the information, each node will have to continue to observe the local environment and respond in an appropriate way.

There are three levels of adaptation:

The first level: design a protocol to deal with the changes such as failure and moving. Basagni movement-adapt to the clustering algorithm is a case in point.

The second level: Design a protocol to meet their parameters as a response to change, in order to optimize the system performance. For example: McDonald’s clustering algorithm, it puts the size of the cluster as a function of mobility level in observed network to adapt the changes.

The third level: Design a protocol to replace the current protocol which can not work because of the serious change. For example, may be the dynamic of the network too high, resulting in a clustering algorithm can no longer carry out cluster functional; it can be based on hierarchical clustering routing switch to flooding.
6. Network model

Self-organizing network model can be expressed as a connected graph \( G(V, E) \), \( V \) which has a characteristic of biological behavior and has the ability to transmit and process is a collection of smart nodes, as the network router; \( E \) is a collection of edge, to represent the link in the networks.

6.1. Network parameters

In order to describe the state of the network, here need to introduce a number of parameters.

1. To the edge we consider the following parameters:

   Total bandwidth (tbw)
   
   Available bandwidth (abw)
   
   Delay dl

   Include the link transmission delay and the delay from its upstream node in processing on the path and communication conversion delay. Assume that the size of the delay achieved by the business which uses the Link has nothing to do with the type of business, only have relations with the type of the link and the network state at that time;

   Delay-Jitter (jt)

   it means the Delay-Jitter from its upstream node in processing on the path;

   Error Rate (ls)

   Include the link transmission error rate and the error rate from its upstream node in processing on the path. Assume that the size of the error rate achieved by the business which uses the Link has nothing to do with the type of business, only have relations with the type of the link and the network state at that time;

2. To the node we consider the following parameters:

   Stability (st)

   Because in the self-organizing network nodes have biological characteristics, they may occur status change at
any time and cause failure, but the routing failure is not hoped by us. So, here we define the stability of the node to say the state how the nodes can maintain the same degree of stability, the nodes having a higher stability should be focus on the consideration when the routing.

6.2. The design of the network behavior

Self-organizing network nodes have acts of biological diversity characteristics, in this article the network behavior was designed as following;

1. Birth

   The new node generation needs the information to initialize.

2. Environment-aware

   * Nodes perceive the parameters of connected link

      Perceive the connected edge of total bandwidth, available bandwidth, delay, jitter and error rate.

   * Perceive the status information of adjacent nodes

      Perceive the load and stability of adjacent nodes.

3. The establishment/elimination of Relations

   * Establish a more efficient edge

      With running of the routing algorithmic, the nodes in the network will gradually accumulate some of the path to the other nodes; here we called these path worldlet edges. And sometimes, worldlet edge can be directly used as the next hop of routing process, with such a worldlet edge has been chosen successfully in the next hop, we will be able to find that the source and the purpose nodes which connected by these edges are often used to a path, so that the two nodes should consider to establish a direct edge.

      Here the main consideration is the using frequency of the worldlet edge between the two nodes in a period of time, only when the worldlet edge is frequently used in routing we consider doing a direct link with the worldlet edge.

      In each of worldlet edges which are saved by the nodes set a counter, after every time the worldlet edge has been
successfully used to get purpose node, accordingly the counter of the worldlet edge adds 1, but the counter is cyclically cleared to update.

Here set when the counter value of a worldlet edge exceed the using time of the existing edge, then create a request that establish a direct high-performance edge from worldlet edge.

* Establish a enhanced edge

When the margin between the two nodes in the next hop options, because they can not meet the requirements of QoS frequently abandoned the election, showed that while this may be the need to strengthen the QoS parameters in order to be able to provide better services for each edge to set a counter abandon election. For a period of time, if a certain edge abandoned the election to reach a certain threshold number, will be aimed at strengthening the edge of the border to generate requests.

* Delete edge

When the two nodes found that the edge between them almost never be selected, we can remove the edge. Here we set up a counter for each edge, whenever a edge has been chosen into the routing path, the counter of the corresponding edge add 1, the counter is cleared from time to time.

After the node dead the edge with it should be removed.

4. Load migration

In order to balance the network load, rationally use resources, in the self-organization node we induct load migration, here the migration does not mean the physical relocation, the node does not physically move from one location to another different location, but shares the neighbor nodes load.

The benefits of this load migration are that nodes do not have to move a long distance, and do not need to be completely divorced from the original function and even can completely continue the original service, but only have additional functions.

Since the migration is for balancing load, optimizing the use of resources, to determine the basis for whether to migrate
and the direction of the migration is the load.

Here, by the different triggered ways the load will be moved into active migration and passive migration.

+ Passive migration

Passive migration were forced to migrate the load under the case of overload, can not be self-supporting, or it would happen serious packet loss, it makes the load balance.

Node through monitoring its own load, when the load continue heavy for a long time delta(t2), this node will issue a request for migration to the neighbor nodes. The neighbor nodes which received a request for study its own load. If the load is light, they may decide to accept the migration.

+ Active migration

Active migration is that when a node finds its own load is light, it will actively view whether there are neighbor nodes with a heavier load around it. If so, it can transfer the load from neighbors; this plays a role in optimizing the use of resources.

By monitoring its own load, when the load continue light for a long time delta(t3), the node further studies the load of its neighbor nodes, if the load of its neighbor nodes are heavier for a period of time delta(t3), the node migrates the load from the neighbors.

Here, there should be delta(t1) < delta(t2) < delta(t3).

5. Clone

Cloning means that copy information from one node to another new node. The new node has the information of the cloned node; it can work as the cloned node. The new node can be used to replace the cloned node, also can be used to share the load from the cloned node.

6. Reproduction
Reproduction is mean that two or more nodes make the information integrate into a node. In this way, the reproduced nodes have several nodes of information; can be used to replace a number of nodes carrying out the work.

7. Dormancy

When the node does not have task over a period of time, the node can be dormant to reduce power consumption;

8. Coma

Because of software errors or non-fatal error cause nodes being unable to work for the time, the nodes though automatically resume over a period of time or the help from out edge world can continue to work.

9. Wake up

Wake up the node in a coma or dormant to continue to work. If in the routing process, the current node does not have the right next hop routing to choose, it needs to wake up dormant neighbors, than the neighbors bring into the next hop.

10. Awake

The node in a coma or dormant will automatically wake up after a period of time and then start running.

11. Save the wake

Through a certain degree of outside interference, the node in a coma can recover, and can be back to work.

12. death

When the node faces of hardware failure or a fatal error, resulting in death, it can no longer work.

6.3. Node stability depict

1. The stability of factor descriptions

In the self-organizing network some of the acts would create instability in the node, for example: node migration, dormancy, coma and death and so on, and in most cases these acts have relationship with the node load, here we have the nodes stability of factor do the following portray:
+ External factors

Here, the external factors which impact the node stability, refer to the load of the neighbor nodes. The neighbors load affects the node migration, if neighbors load is heavy; the node is likely to accept the migration of neighbor nodes to share the load. If the neighbors load is light, the possibility of the node migration is very small.

+ Self factors

Here the self factor mainly refers to the self-node load. The self-node load of is a double factor, on the one hand, when the load of the self-node is heavy, the node is likely to occur in coma or even death behavior; on the other hand, when the node load is light, the node is likely to occur migration or dormancy behavior. Therefore, to the self-node factor, when the node load is neither heavy nor light, it was the most stable, too heavy or too light will lead to instability.

2. Stability calculation

With the discussion to the stability factors, we know that the nodes can portray the node stability through their own load and their neighbors load.

First of all, discuss how to specifically describe the nodes load. Here we induct two parameters, the CPU cycle ACPU which can be used by nodes and the buffer zone ABUF which can be used by nodes. For a node, the greater value of the two parameters above, the higher processing power which the nodes can be used and the lighter load to their own node, on the contrary the more serious.

In order to be able to integrate the two parameters ACPU and ABUF with different units into a formula, here we use the form of the useable value can be accounted for the percentage of the total value to indicate the value of the two parameters. For a node, the node can directly get the total number of the CPU cycles TCPU and the total size of the buffer zone TBUF, as well as the currently available CPU cycles ACPU and the currently available size of the buffer zone ABUF.

The value of cycle CPU and the value of the BUF can be used for calculating, the formula like (3.1) and (3.2).
VACPU=ACPU/TCPU (3.1)

VABUF=ABUF/TBUF (3.2)

The value of the VACPU and the value of the VABUF are between 0 and 1, the greater the value of the two is, it shows that the lighter the node load is, and the node load calculation formula is:

\[
\text{LOAD} = \frac{a}{\text{VACPU}} + \frac{b}{\text{VABUF}} \quad (3.3)
\]

\[a, b < 0 \& a + b = 1, \quad 1 \leq \text{LOAD} < \infty.\]

In the formula, when the VACPU and the VABUF have taken a zero value, we consider the node load is infinite, and do not need to calculate.

The above-mentioned formula is meaning: when the node CPU cycles and the buffer witch can be used are large, the node load is light, in other words the value of the load is less; and when the one or both are less, the node load is heavy, in other words the value of the load is larger.

After we get the node load formula, we can depict the node stability in accordance with the above description, and the node stability is ST, the value of ST is greater, the node stability is higher, as (3.4).

\[
\text{ST} = \frac{a}{\text{LOAD(neighbor)}} + b \times (1 - 2 \times |\frac{1}{\text{LOAD}} - \frac{1}{2}|) \quad (3.4)
\]

\[a, b > 0 \& a + b = 1.\]

In formula (3.4), the first is the factor of a neighbor node load, \(\text{LOAD(neighbor)}\) on behalf of the neighbor nodes load, and the node has lots of neighbors, so get the value witch is the heaviest load in its neighbor nodes. Because when the node transfer it is most likely to move toward the heaviest load of the neighbors, namely:

\[
\text{LOAD(neighbor)} = \max\{ \text{LOAD(i)} \} \quad (3.5)
\]

\(\text{LOAD(i)}\) is the No.i neighbor node load, \(0 < \frac{1}{\text{LOAD(neighbor)}} \leq 1\), this is mean that the value of \(\text{LOAD(neighbor)}\) is larger, the value of ST is less, contrarily is lager.

The second is the factor of the node’s self load, \(\text{LOAD}\) is the value of the node’s self, \(0 < \frac{1}{\text{LOAD}} \leq 1\), so \(0 \leq |\frac{1}{\text{LOAD}} - 1|\) \(\leq 1/2\), accordingly \(0 \leq (1 - 2 \times |\frac{1}{\text{LOAD}} - \frac{1}{2}|) \leq 1\), when the
value of 1/LOAD is closely to 1/2, Nodes, the degree of node
stability is higher, when the value of 1/LOAD is far away from
1/2, the degree of node stability is lower. Here, the reason
why the middle value is 1/2: according to the formula, when
there is the value of the CPU VACPU and the value of the
buffer zone which can be used VABUF are all 1/2, LOAD = 2, so
1/LOAD = 1/2.

The signification of the formula (3.4) is: the load of the
neighbor node become heavier, the node stability become
lighter, contrarily is hoist; the load of the node become
heavier or lighter, the node stability are lower, in the
middle value, the node stability become higher.
7. User demands

User demand is the requirements of the internet users on the QoS parameters of the communication line. As the state of the network is imprecise what make the user demands indefinite, so use a series of range to express.

7.1. Unicast user demands

Define the user QoS request is \( R(v(s), v(d), \delta_{bw}(L), \delta_{bw}(H)), \delta_{dl}(L), \delta_{dl}(H), \delta_{jt}(L), \delta_{jt}(H), \delta_{ls}(L), \delta_{ls}(H), p) \). \( v(s) \) belonging to \( V \) is the source node, \( v(d) \) belonging to \( V \) is the purpose node, \( \delta_{bw}(L), \delta_{bw}(H) \) is the bandwidth demand range, \( \delta_{dl}(L), \delta_{dl}(H) \) is the delay demand range, \( \delta_{jt}(L), \delta_{jt}(H) \) is the Delay-Jitter demand range, \( \delta_{ls}(L), \delta_{ls}(H) \) is the error rate demand range, \( p \) is the ceiling of the cost what the users want to pay. Unicast routing is to find a path \( P(sd) \) from \( v(s) \) to \( v(d) \), request its available bottleneck bandwidth, total delay of the path, the total Delay-Jitter of the path, the total error rate of the path Respectively falls in \( \delta_{bw}, \delta_{dl}, \delta_{jt}, \delta_{ls} \).

7.2. Multicast user demands

Multicast users, everyone in the group has its own end-to-end QoS demand, for member \( v(d) \), QoS demand is \( R(v(s), v(d), \delta_{bw}(L), \delta_{bw}(H)), \delta_{dl}(L), \delta_{dl}(H), \delta_{jt}(L), \delta_{jt}(H), \delta_{ls}(L), \delta_{ls}(H), p(d) \), \( \delta_{bw}(L), \delta_{bw}(H) \) is the bandwidth demand range, \( \delta_{dl}(L), \delta_{dl}(H) \) is the delay demand range, \( \delta_{jt}(L), \delta_{jt}(H) \) is the Delay-Jitter demand range, \( \delta_{ls}(L), \delta_{ls}(H) \) is the error rate demand range, \( p(d) \) is the ceiling of the cost what the users want to pay.

In the isomorphism multicast, the demands of each group members are the same.
8. Link satisfaction

8.1. The illegible description of the Link parameter

As the network is dynamic, this led to the Inaccuracy of the information network, so in fact the link parameters are very difficult to accurately expressed, so here we import fuzzy math knowledge to describe the link parameters. Link parameters are expressed by the form of range of, and then calculating the membership degree of the range.

1. Available bandwidth

Assume the value range of the available bandwidth \( abw(l) \) on the link \( e(l) \) is \([abw(L, l), abw(H, l)]\), if user application bandwidth is \( bw \), bandwidth membership degree function:

\[
f(l, abw, bw) = \begin{cases} 
1 , & bw \leq abw(L, l) \\
1/2 - 1/2 \sin\left(\frac{\pi}{abw(H, l) - abw(L, l)} \cdot \frac{bw - (abw(L, l) + abw(H, l))}{abw(H, l) - abw(L, l)}\right) , & abw(L, l) < bw \leq abw(H, l) \\
0 , & bw > abw(H, l)
\end{cases}
\] (3.6)

The formula is established on the base of setting the bandwidth membership degree function to obey the smaller form in the mountain-shaped distribution.

2. Delay

Assume the value range of the available bandwidth \( dl(l) \) on the link \( e(l) \) is \([dl(L, l), dl(H, l)]\), if the sharing value of the user application delay on the link \( dl \), bandwidth membership degree function:

\[
f(l, dl, dl) = \begin{cases} 
1 , & dl \leq dl(L, l) \\
1/2 + 1/2 \sin\left(\frac{\pi}{ld(H, l) - dl(L, l)} \cdot \frac{dl - (dl(L, l) + dl(H, l))}{ld(H, l) - dl(L, l)}\right) , & dl(L, l) < dl \leq dl(H, l) \\
0 , & dl > dl(H, l)
\end{cases}
\] (3.7)

The formula is established on the base of setting the delay membership degree function to obey the smaller form in the mountain-shaped distribution.
3. Delay-Jitter

Assume the value range of the Delay-Jitter bandwidth $jtl$ on the link $el$ is $[jt(L, l, jt(H, l))]$, if the sharing value of the user application Delay-Jitter on the link $jt$, bandwidth membership degree function:

$$f(l, jt, jt)=\begin{cases} 1, & jt<=jt(L, l) \\ 1/2+1/2\sin\left\{\pi/\left[jt(H, l)-jt(L, l)\right]\right\}, & jt(L, l)<jt<=jt(H, l) \\ 0, & jt>jt(H, l) \end{cases} \quad (3.8)$$

The formula is established on the base of setting the Delay-Jitter membership degree function to obey the smaller form in the mountain-shaped distribution.

4. Error rate

Assume the value range of the error rate bandwidth $lsl$ on the link $el$ is $[ls(L, l, ls(H, l))]$, if the sharing value of the user application error rate on the link $ls$, bandwidth membership degree function:

$$f(l, ls, ls)=\begin{cases} 1, & ls<=ls(L, l) \\ 1/2+1/2\sin\left\{\pi/\left[ls(H, l)-ls(L, l)\right]\right\}, & ls(L, l)<ls<=ls(H, l) \\ 0, & ls>ls(H, l) \end{cases} \quad (3.9)$$

The formula is established on the base of setting the error rate membership degree function to obey the smaller form in the mountain-shaped distribution.

8.2. Satisfaction function

Setting the user’s end-to-end QoS requirement, bandwidth constraints range $\delta(bw)=[bw_r(L, ), bw_r(H, )]$, delay constraints range $\delta(dl)=[dl_r(L, ), dl_r(H, )]$, Delay-Jitter constraints range $\delta(jt)=[jt_r(L, ), jt_r(H, )]$, error rate constraints range $\delta(ls)=[ls_r(L, ), ls_r(H, )]$, next give the QoS Satisfaction function on the link.
1. Bandwidth

Assume the Occupied bandwidth on the link el is bw, the bandwidth satisfaction function on the link is:

\[ S(l, bw, bw) = 0 \text{ , } bw < bw_r(L, ) \]

\[ S(l, bw, bw) = e^{-((bw_r(H, ) - bw) / (bw - bw_r(L, )))^2} \text{ , } bw_r(L, ) \leq bw < bw_r(H, ) \]

\[ S(l, bw, bw) = 1 \text{ , } bw_r(L, ) \leq bw < bw_r(H, ) \] (3.10)

The formula shows that the larger the value is, the more the satisfactory of user’s bandwidth is, the largest value of the satisfaction is 1.

2. Delay

By the following principles:

\[ \delta(l, dl) = [dl_r(L, l), dl_r(H, l)] \] (3.11)

\[ dl_r(L, l) = dl / \sigma(dl(i), e(i) \text{ belonging to } P) * dl_r(L, ) \] (3.12)

\[ dl_r(H, l) = dl(i) / \sigma(dl(i), e(i) \text{ belonging to } P) * dl_r(H, ) \] (3.13)

Assume the actual delay on the link el is dl1, the delay satisfaction on the link is:

\[ S(l, dl, dl) = 1 \text{ , } dl < dl_r(L, l) \]

\[ S(l, dl, dl) = 1 - e^{-((dl_r(H, l) - dl) / (dl - dl_r(L, l)))^2} \text{ , } dl_r(L, l) \leq dl < dl_r(H, l) \]

\[ S(l, bw, bw) = 0 \text{ , } dl < dl_r(H, l) \] (3.14)

The formula shows that the delay satisfaction on the link is with the actual delay increase and decrease.

3. Delay-Jitter

The character of the Delay-Jitter is similar to the character of the delay, calculation methods of the satisfaction are also same, and next we give the formula.
delta( ,jt)=\begin{bmatrix} jt_\text{r}(L, l) \\ jt_\text{r}(H, l) \end{bmatrix} 
\quad \text{(3.15)}

jt_\text{r}(L, l)=jt( , l)/\sigma(jt( , i), e(i) \text{ belonging to } P)*jt_\text{r}(L, ) 
\quad \text{(3.16)}

jt_\text{r}(H, l)=jt( , l)/\sigma(jt( , i), e(i) \text{ belonging to } P)*jt_\text{r}(H, ) 
\quad \text{(3.17)}

Assume the actual Delay-Jitter on the link el is \( jl \), the Delay-Jitter satisfaction on the link is:

\[ S(l,jt,jt)= \begin{cases} 1 & \text{if } jt<jt_\text{r}(L, l) \\ 1-e^{-((jt_\text{r}(H, l)-jt)/(jt-jt_\text{r}(L, l)))^2} & \text{if } jt_\text{r}(L, l)<=jt<jt_\text{r}(H, l) \\ 0 & \text{if } jt<jt_\text{r}(H, l) \end{cases} \] 
\quad \text{(3.18)}

4. Error rate

\[ \delta( , ls)=\begin{bmatrix} ls_\text{r}(L, l) \\ ls_\text{r}(H, l) \end{bmatrix} \quad \text{(3.19)}\]

\[ ls_\text{r}(L,l)=1-(1-ls( , l))^*((1-ls_\text{r}(L, ))/\pi(1-ls( , i)))^{(1/p)} \quad \text{(3.20)} \]

\[ ls_\text{r}(H,l)=1-(1-ls( , l))^*((1-ls_\text{r}(H, ))/\pi(1-ls( , i)))^{(1/p)} \quad \text{(3.21)} \]

Assume the actual error rate on the link el is \( ls_1 \), the error rate satisfaction on the link is:

\[ S(l,ls,ls)= \begin{cases} 1 & \text{if } ls<ls_\text{r}(L, l) \\ 1-e^{-((ls_\text{r}(H, l)-ls)/(ls-ls_\text{r}(L, l)))^2} & \text{if } ls_\text{r}(L, l)<=ls<ls_\text{r}(H, l) \\ 0 & \text{if } ls<ls_\text{r}(H, l) \end{cases} \] 
\quad \text{(3.22)}

8.3. The computing of the Link satisfaction

1. Bandwidth satisfaction calculation

The bandwidth value of a link is \( abw_\text{r}(L, ), abw_\text{r}(H, ) \), in communications users actually occupied bandwidth is \( ubw \), so define the evaluation function of the occupied bandwidth by the users on the link as the following:
\[ g(l, \text{bw}) = f(l, \text{bw}, \text{ubw}) \times S(l, \text{bw}, \text{ubw}) \quad (3.23) \]

\( f(l, \text{bw}, \text{ubw}) \) and \( S(l, \text{bw}, \text{ubw}) \) are Bandwidth membership and satisfaction, getting from the formulas (3.6) and (3.10).

2. Delay faction calculation

Similarly, the delay value range of a link is \([d_l(L, ), d_l(H, )]\), in communications users actually delay is \(u_d\). So we define the Delay for membership function is:

\[ g(l, \text{dl}) = f(l, \text{dl}, u_d) \times S(l, \text{dl}, u_d) \quad (3.24) \]

\( f(l, \text{dl}, u_d) \) and \( S(l, \text{dl}, u_d) \) are delay membership and satisfaction, getting from the formulas (3.7) and (3.14).

3. Delay-Jitter satisfaction calculation

Similarly, the Delay-Jitter value range of a link is \([j_t(L, ), j_t(H, )]\), in communications users actually Delay-Jitter is \(u_j\). So we define the Delay-Jitter for membership function is:

\[ g(l, \text{jt}) = f(l, \text{jt}, u_j) \times S(l, \text{jt}, u_j) \quad (3.25) \]

\( f(l, \text{jt}, u_j) \) and \( S(l, \text{jt}, u_j) \) are Delay-Jitter membership and satisfaction, getting from the formulas (3.8) and (3.18).

4. Error rate satisfaction calculation

Similarly, the error rate value range of a link is \([e_s(L, ), e_s(H, )]\), in communications users actually error rate is \(u_e\). So we define the error rate for membership function is:

\[ g(l, \text{ls}) = f(l, \text{ls}, u_e) \times S(l, \text{ls}, u_e) \quad (3.26) \]

\( f(l, \text{ls}, u_e) \) and \( S(l, \text{ls}, u_e) \) are error rate membership and satisfaction, getting from the formulas (3.9) and (3.22).

Integrate bandwidth, delay, and Delay-Jitter and error rate for evaluation of the link; get the satisfaction value formula of the link \(e(l)\):

\[ W(l) = a_{\text{bw}} \times g(l, \text{bw}) + a_{\text{dl}} \times g(l, \text{dl}) + a_{\text{jt}} \times g(l, \text{jt}) + a_{\text{ls}} \times g(l, \text{ls}) \quad (3.27) \]

\( a_{\text{bw}} \), \( a_{\text{dl}} \), \( a_{\text{jt}} \), and \( a_{\text{ls}} \) are their own weight factor of the Qos parameter, \( a_{\text{bw}} \), \( a_{\text{dl}} \), \( a_{\text{jt}} \), \( a_{\text{ls}} \) belonging to [0
1), and $a(d_l)+a(d_l)+a(d_l)+a(d_l)=1$, $W_l$ is the value between 0 and 1.
9. The avail computing and the game analysis

According to the principles of economics, the prices of the commodity should be based on the current development of market supply and demand, while at the same time the price affects the supply and demand.

In order to improve the quality of the network, users will as far as possibly take up as more as bandwidth on the link, but this will lead to network resources in short supply, so that network operators will raise prices, so users should pay more. In order to increase revenue, network operators increase the price of network resources, but this would allow users refused to use their network of resources; it reduces the operator’s revenue. As a result operators will have to cut prices to attract customers. As a result, users should be based on the current pricing decision to take up the number of network resources to maximize their own interests; network operators should be based on current supply and demand situation to decide how resources should be pricing in order to maximize profits.

In routing, using those links which the error rate and delay is small can improve the quality of the communications network. However, good quality link need to pay high costs, so in Link delay, jitter and error rate charges will affect the users’ avail and the operators’ revenue.

9.1. The cost and the price

The cost is the cost of resources from providing the network service by network providers, the unit cost of the bandwidth resources cb of the link el, if the distributive bandwidth is ubw, the cost of the network providers is:

\[ \text{Cost}(l) = c(d) \times \text{ubw} \]  

(3.28)

The price is the charge that the users pay for using the network resources, for link el, the price is:

\[ \text{Pay}(l) = p \times \text{ubw} \]  

(3.29)

In the formula, p is the price of the bandwidth (unit time), its value has relationship with the Network utilization, when the Network utilization is high, the network resources will enhance p, but when the Network utilization is low, the network resources will reduce p. The strategy like:

\[ p = p(\text{min}), h < h(\text{min}) \]
p = c(b) * (1 + a * h(-2, 0)) / (1 + a * h(-2, 0)) , h(min) <= h < h(0)

p = c(b) * [2 - e^(-k(h-h(0)))] , h(0) <= h < h(max)

p = p(max) , h(max) <= h < h(1) (3.30)

c(b) is the unit cost of the bandwidth resources, p(min), p(max) is set by network providers.

a = (c(b) - p(min)) / (p(min) * h(-2, min) - c(b) * h(-2, 0)),

k = ln(2 - p(max) / c(b)) / (h(max) - h(0))^2.

h is the link bandwidth using rate, definition:

h = (tbw - abw) / tbw (3.31)

Table1 Floating Price

<table>
<thead>
<tr>
<th>Delay</th>
<th>Jitter</th>
<th>Error rate</th>
<th>Floating Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>delta(1, dl)</td>
<td>delta(1, jt)</td>
<td>delta(1, ls)</td>
<td>p(f1)</td>
</tr>
<tr>
<td>delta(2, dl)</td>
<td>delta(2, jt)</td>
<td>delta(2, ls)</td>
<td>p(f2)</td>
</tr>
<tr>
<td>delta(3, dl)</td>
<td>delta(3, jt)</td>
<td>delta(3, ls)</td>
<td>p(f3)</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>delta(k, dl)</td>
<td>delta(k, jt)</td>
<td>delta(k, ls)</td>
<td>p(fk)</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Figure 1

delta(k, dl)=[dl(k, low), dl(k, high)],
delta(k, dl)=[dl(k, low), dl(k, high)],
delta(k, jt)=[jt(k, low), jt(k, high)],
delta(k, ls)=[ls(k, low, jt(k, high))].

9.2. The computing of the Link avails

Here, we use the avail to describe the level of earnings which the use to of the users and the network providers get in the process of routing.

The user avail on the link is uu(l):

UU(l) = W(l) * (p(l) - pay(l)) / p(l) (3.32)
The network providers avail on the link has a relationship with the cost and the charge, the network providers avail on the link e(l) is:

\[ \text{Un}(l) = \frac{(\text{Pay}(l) - \text{Cost}(l))}{\text{Cost}(l)} \quad (3.33) \]

There into, the user link satisfaction is W(l), on the link the e(l) the ceiling which the user wants to pay is p(l) (time unit), the user’s ceiling is Pay(l), the link cost is Cost(l).

9.3. The game analysis

When a game happens on a link, the user strategy is an m-levels bandwidth allocation: ubw(1), ubw(2), ubw(3), ubw(4), here ubw(i) expresses under the No.i user strategy that the link bandwidth which the user chooses.

Network operators’ strategies are set n types of price for the link: P(1)P(2)...P(n). Different levels price correspond to the different link superiority.

Users select a bandwidth, network providers select a price, there is a corresponding QoS parameters and the costs, we can get the users avail and the network providers avail.

Define the avail matrix \( R(m \times n) \)=[uu(ij), un(ij)](m*n) on the link, the matrix elements (uu(ij), uu(ij)) express that under the strategy group (ubw(i), P(j)), the avail of the users is uu(ij) and the avail of the network operators is uu(ij). The purpose of the game is to find out the “best” strategy group (ubw(i), P(j))(best) which the avails of the both sides reach together.

According to the definition of the Nash equilibrium, the avail matrix achieves the element of the Nash equilibrium:

\[ \text{uu}(ij) \Rightarrow \text{uu}(i(*)j), i(*) = 1,2,3^m \]
\[ \text{un}(ij) \Rightarrow \text{un}(ij(*)), i(*) = 1, 2, 3^n \quad (3.34) \]

If we find the element, the group of the node corresponding strategy (ubw(i), P(j)) is the group of the Nash equilibrium on the link.

If we find the element of the Nash equilibrium, the group of the node corresponding strategy (ubw(i), P(j)) is the strategy of the Nash equilibrium on the link e(l). The definition is:

\[ \text{pareto}(ij)=1/(a/\text{uu}(ij)+b/\text{un}(ij)) \quad (3.35) \]

a and b are the tilt value of the users and the network operators, a,
b > 0. User this formula, what make the value of pareto(ij) be a larger element is the better Pareto.
10. The path and multicast tree evaluation

Here, there are two factors to evaluate the pros and cons of the path or the multicast tree, namely: the users’ avails, network providers’ avails. The purpose to optimize the objectives is: to maximize the avail of users, to maximize the network providers’ avails and to maximize the sum of users and network providers’ avails and reach a win-win situation. Through the following path and multicast tree evaluation formula to achieve the optimization goal.

Here we definite the evaluation value of the path P and the evaluation value of the multicast tree T, the formula like:

\[ J(p) = \frac{a(up)}{UU(P)} + \frac{a(np)}{UN(P)} \]  
\[ J(T) = \frac{a(ut)}{UU(T)} + \frac{a(nt)}{UN(T)} \]

\[ 0 < a(up), a(np) < 1, a(up) + a(np) = 1 \]

\[ 0 < a(ut), a(nt) < 1, a(ut) + a(nt) = 1 \]

\[ UU(P) \text{ or } UU(T) \text{ is the user on the path } UU(P) \text{ or } UU(T) \text{ or the multicast tree, } UN(P) \text{ or } UN(T) \text{ is the network providers' avail, the calculation methods are like the formulas (3.38), (3.39), (3.40) and (3.41).} \]

The formula is used to calculate the user avail of the path P and the user avail of the multicast tree T as the following:

\[ UU(P) = \frac{\sum uu(l), l \text{ belonging to } P}{L(P)} \]  
\[ UU(T) = \frac{\sum \sum uu(i, l), l \text{ belonging to } (s-i), l \text{ belonging to } T}{L(T)} \]

The formula is used to calculate the network providers’ avail of the path P and the network providers’ avail of the multicast tree T as the following:

\[ UN(P) = \frac{\sum un(l), l \text{ belonging to } P}{L(P)} \]  
\[ UN(T) = \frac{\sum un(l), l \text{ belonging to } T}{L(T)} \]

\[ L(P) \text{ compose the number of the path } P, L(T) \text{ compose the number of the multicast tree } T. \]
11. Mathematics model

11.1. Unicast mathematics model

In the unicast QoS routing, optimizing objectives is: in the case of satisfying the QoS constraints, maximize the effectiveness from users, network operators and the sum of the effectiveness from users and network providers, and make the effectiveness from users and network providers achieve a win-win situation.

There is:

\[ UU(P) \rightarrow \max\{UU(P)\} \quad (3.42) \]
\[ UN(P) \rightarrow \max\{UN(P)\} \quad (3.43) \]
\[ UU(P) + UN(P) \rightarrow \max\{UU(P) + UN(P)\} \quad (3.44) \]

s.t. main(\{abw\}, e(l) is belonging to P(sd)) \Rightarrow bw_r(, l) \quad (3.45)
\[ \sigma(dl(, l), e(l) is belonging to P(sd)) \leq dl_r(, h) \quad (3.46) \]
\[ \sigma(jt(, l) \leq jt_r(, h), e(l) is belonging to P(sd)) \quad (3.47) \]
\[ 1-pi((1-ls(, l)) e(l) is belonging to P(sd)) \quad (3.48) \]
\[ pay(, p) \leq p \quad (3.49) \]

11.2. Mathematics model

In the multicast QoS routing, optimizing objectives is: in the case of satisfying end-to-end QoS constraints for all the users, maximize the effectiveness from users, network operators and the sum of the effectiveness from users and network providers.

There is:

\[ UU(T) \rightarrow \max\{UU(T)\} \quad (3.50) \]
\[ UN(T) \rightarrow \max\{UN(T)\} \quad (3.51) \]
\[ UU(T) + UN(T) \rightarrow \max\{UU(T) + UN(T)\} \quad (3.52) \]

s.t. main(\{abw(d, l)\}, e(l) is belonging to P(sd)) \Rightarrow bw_r(d, l) \quad (3.53)
\[ \sigma(dl(d, l), e(l) is belonging to P(sd)) \leq dl_r(d, h) \quad (3.54) \]
\[
\sigma(j_t(d, l) \leq j_t_r(d, h), e(l) \text{ is belonging to } P(sd)) \quad (3.55)
\]

\[
1 - \pi((1 - l_s(d, l)) e(l) \text{ is belonging to } P(sd)) \quad (3.56)
\]

\[
\text{pay}(d, p) \leq p(d) \quad (3.57)
\]

In the Isomorphism Multicast, the value of \(bw_r(d, l), dl_r(d, h), j_t_r(d, h)\) is the same.
12. Worldlet behavior

1. the acts of the worldlet behavior have the following characteristics

* The high variability of the node degree distribution can get a short path and a high clustering coefficient;

* When the variability of the node degree is not very high, it alone can not cause a worldlet behavior;

* Preference for local connections can cause a worldlet behavior, especially in the router-level network topology;

Self-organizing network has the biological characteristics, the node is dynamic, and the edge can also be established or removed, so the degree of the node is variable. In addition, in the self-organizing networks the interaction between the nodes is localized, also means that preferred local connection. But, there requires a process to evolve from the random network to the networks with a clear worldlet behavior, during the period may not directly use the worldlet characteristics to process routing. Another point, in the current worldlet network, the connection between the nodes refers to directly connection, this means that the node degree of variability also referring to the edge with directly physical connection. Here, we can use non-direct connection edge to act as a direct connection edge to produce worldlet behavior in order to get the advantage, which is in the section 3.1.2; we have mentioned the worldlet edge in the design of the organizational behavior.

For example, the node A is directly connected to the nodes A1, A2, A3, A4, but the source node routing from A has established, the purpose nodes are D1, D2, D3, from A to D1, D2, D3, respectively exist worldlet edge. When we calculating the degree of A we take all three worldlet edge s into account.

Of course, to regard the path as an edge can bring a very favorable result; also cause some problems, after all, in the process of routing the complexity of dealing with a path is it not exactly the same as the complexity of dealing with a real edge to deal with.

Sometimes this way leads to another problem, through the worldlet to find the path need a few steps, but the actual path of the hop may be a lot of, so it is not a better path.
In order to avoid the many times to induct the worldlet edge result in the above problem, in a routing process we should limit that only in the last hop we can induct the worldlet edge.

In this way, we can greatly reduce the problems described above, and the path which was introduced from introducing the worldlet edge, if the performance is not good, it will be eliminated gradually by optimization arithmetic. In addition, in a dynamic environment of self-organizing network, quickly reaching the second best is often more meaningful than optimal.

2. In the self-organizing network realize worldlet behavior

* Utilize the worldlet edge

With the process of algorithm, the node will have accumulated some worldlet edge. With the increasing of the worldlet edge, the number of the nodes which can be reached will be more and more, in the back of the routing process, we can directly use the accessible worldlet edge information to speed up the process of routing.

The record of the worldlet path from the current node is like the following table 2.

<table>
<thead>
<tr>
<th>purpose</th>
<th>intermediate nodes sequence</th>
<th>hop</th>
<th>next hop</th>
<th>using times</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(1)</td>
<td>(N(1),...)</td>
<td>5</td>
<td>N(1)</td>
<td>m(1)</td>
</tr>
<tr>
<td>D(2)</td>
<td>(N(4),...)</td>
<td>3</td>
<td>N(4)</td>
<td>m(2)</td>
</tr>
<tr>
<td>D(3)</td>
<td>(N(4),...)</td>
<td>3</td>
<td>N(4)</td>
<td>m(3)</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Figure 2

Initialization: each node has a table of the worldlet edge, when the initial, the table is empty.

Adding: To be completed by the algorithm, when every time the algorithm successes to find a path, it puts the path information into the table of the worldlet path, the value
"used to be counted" is 0.

Count: When every time a worklet edge has been successfully used to reach the destination node, the value of the "be used times" of the worldlet edge will be added by 1.

Update: Every delta(t(swp)) it scans the value of the "be used times", to delete those lines whose value is 0, and then clear the value "by using times" of the retained lines.

3. The success rate of node routing

It means the percentage of succession times in the nodes total number of routing. The node with a higher success rate is more credible in the routing more reliable.

The success rate formula of the computing node i:

\[ I(i) = \frac{rcs(i)}{rct(i)} \] (3.58)

4. According to the structure of the address

The node with the same IP address prefix is likely to be close to the region, and he longer the part of the same prefix, the more likely to located closer to the region, here we call such characteristic the similar degree.

The calculation of the two addresses similar degree take the following method: scan the 32-bit address from left to right bit-by-bit comparing the binary bit, if they are different, records of the same bit M(ik), the similar degree is V(i):

\[ V(i) = \frac{M(ik)}{32} \] (3.59)
13. The route strategy based on self-organizing network

Self-organizing network has a lot of characteristics such as local, dynamic, complicated, and so on. In the initial stage of building up the self-organizing networks, we require to use distributed routing algorithm for routing. With the self-organizing network gradually into the relatively stable state, through the environment perception of the self-organization behavior protocol and the collection of the network topology, centralized routing algorithm can be used in routing, to improve the routing efficiency and success rate.
14. Security considerations

Security is a major problem in the self-organizing network. The entities in Self-organizing system directly interact in a distributed peer-to-peer manner, a simple act of each entity will be able to form a complex behavior of the whole system. Under such a mechanism the identity of the entity and conduct surveillance become very difficult, For the malicious entities which intruded into the self-organizing network we can not carry an effective screening and prevention, and easily to be eavesdropped and attacked. Therefore, we need to research the security architecture and security technologies which apply to the self-organizing network. This article describes the self-organizing network model which is the mainly focus on self-organizing network of the basic network structure and the related QoS routing factors, but not discuss the security technology of the self-organizing network.
15. IANA Considerations

This document has no actions for IANA.
16. Acknowledgments

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