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FuzzyAcoRouter: An Efficient Network Packet Routing Algorithm Based on Mixing Fuzzy Control System and ACO

[1]Mirsaeid Hosseini Shirvani and [2]Seyed Majid Hosseini Shirvani
[1]Department of Computer Engineering, Sari Branch, Islamic Azad University, Sari, Iran
[2]Department of Computer Engineering, Babol Branch, Islamic Azad University, Babol, Iran

Abstract: This study discusses new proposed Fuzzy AcoRouter. The aim of this study is to find optimal path for networks packet routing with satisfying QOS parameters. To make good decision, this method uses fuzzy control system and swarm intelligent tools. The result illustrates Fuzzy AcoRouter has more performance in QOS metrics in comparison with other standard routing protocols like OSPF. It will pave the way to apply intelligent method in next routing protocol generations..

Keywords: ACO, finding optimal, FuzzyAcoRouter, OSPF, QOS

INTRODUCTION

Finding Optimal is being used in some fields such as computer science, artificial intelligence and operation research (Kaveh and Sharafi, 2007). It is applied when we have variety feasible solutions and the objective is to find out not only a solution but also a most efficient one. Many finding optimal problems are categorized into NP-Complete problems whereas time execution will be increased with growing problem dimensions and it will be exponential in the worst case. To solve these problems, there are three basic methods such as structural, improve mental and meta-heuristic algorithms (Dorigo and Stutzle, 2000; Dorigo and Di Caro, 1999). The weaknesses of the first two are to depend on initial state and to stick in local minimal respectively. In this case the sole alternative is meta-heuristic algorithms so that it has high flexibility and represents efficient solutions. Meta-heuristic algorithms are capable to survey high performance solutions in reasonable time especially on complicated finding optimal problems. One of the meta-heuristic algorithms is Particle Swarm Optimization (PSO). It was firstly introduced by Kennedy and Eberhart (1995). Its main concepts were inspired from swarm bird's attitude, bunch of fish or flock of animal's manner. PSO includes ACO which stands for Ant Colony Optimization (Dorigo and Stutzle, 2004) Bee etc., (Miri, 2010). For instance, ACO has two types of ants, that is, forward ant and backward ant. Forward ants gather problem details and deliver to backward ants which update problem database and finally it will be applied for next decision making step. One application of finding optimal is related to shortest path in computer networks (Di Caro and Dorigo, 1998). The best internet routing protocols are BGP, RIP, BF and OSPF (Tan, 2011) so that their goal is to find shortest path between source and destination for routing the packets. The cost of path will be determined by some metrics like bandwidth, number of hops, queue length, delay, jitter and congestion. As the instantaneous network traffic is being changed (Di Caro and Dorigo, 1998), some nodes may have congestion when the rest are idle or never being used. In this condition the algorithm rule is load balancing (Schoonderwoerd *et al*., 1996). Through the aforementioned algorithms, OSPF has more trade off than others. For the sake of routing algorithm optimization, we use meta-heuristic ACO in network routing and call it AcoRouter (Mirabedini and Teshnehlab, 2007a) as can be seen in Fig. 1.

Simulation shows that AcoRouter is more optimal than OSPF. Our fulfilled work in this study is to mix AcoRouter with fuzzy control system and to represent FuzzyAcoRouter algorithm (Pasupuleti *et al*., 2011). In this study we propose our algorithm in section 2. Also the result of simulation is in section 3. Finally, the conclusion is given in section 4.

FUZZYACOROUTER ALGORITHM

Fuzzy logic was firstly introduced by Loftizadeh (Zadeh, 1965) and its goal was to conduct and to control industrial systems. The parameters used in new FuzzyAcoRouter method (Tan, 2011) are delay, jitter, queuing, bandwidth, packet loss ratio which are quality of service fundamental parameters, QOS in short. As computing all parameters imposes overhead, we take

Corresponding Author: Mirsaeid Hosseini Shirvani, Department of Computer Engineering, Sari Branch, Islamic Azad University, Sari, Iran

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Procedure AcoRouter ( t , t_end , Δt)
input  t       // Current Time
input  t_end   // Time length of the simulation
input  Δt      // Time interval between ants generation

foreach  i ϵ C do
  M←InitLocalTrafficMode
  Γ←InitNodeRoutingTable
  while t ≤ t_end  do
     in_ parallel      //Concurrent  activity  on  each  node
     if( t mod Δt ) = 0  then
        destination ← SelectDestination( traffic_distribution_at_source )
        LaunchFrowardAnt( source , destination )
     end{ if }
     foreach( ActiveForwardAnt [ source , current  ,  destination ] ) do
       while( current  ≠  destination )  do
          next_hop ← SelectLink ( current  ,  destination ,  link_quesues  ,  Γ )
          PutAntOnLinkQueue( current  ,  next_hop )
          WaitOneDataLinkQueue( current  ,  next_hop )
          Crosslink( current  ,  next_hop )
          Memorize( next_hop ,  elapsed_time )
          current ← next_hop
       end{ while }
       LaunchBackwardAnt( destination , source ,  memory_data )
     end{ foreach }
     foreach( ActiveBackwardAnt [ source ,  current  ,  destination ] ) do
        while( current  ≠ destination ) do
          next_hop ← Popmemory
          WaitOnHighProiorityLinkQueue ( current  ,   next_hop )
          from ← current
          current ←  next_hop
          UpdateLocalTrafficModle( M , current , from , source ,  memory_data)
          R ← GetNewPheremone( M , current , from , source , memory _data )
          UpdateLocalRoutingTable( Γ , current , source , R )
       end{ while }
     end{ foreach }
     end{ in_parallel }
  end{ while }
end{ foreach }
end{ AcoRouter }
```

Fig. 1: Acorouter algorithm

into account two effective parameters that are delay and queue length or buffer size for each node therefore we consider x_1 = delay and x_2 = queue length as fuzzy inputs. On the other hand the rest parameters depend on two mentioned parameters. This new method inherits basic attributes of ACO and it has two types of ants, so the forward ants start gathering status quo information especially QOS parameters then forward ants deliver to backward ants (Habibi, 2006). Consequently, fuzzy control make decision update routing table for each node according to the information provided by backward ants. Fuzzy rules scope includes

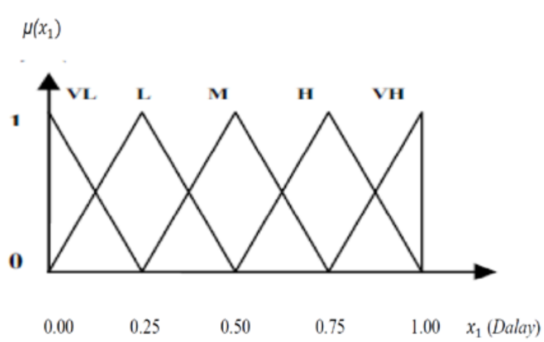

Fig. 2: Membership function for the first input x_1 = delay

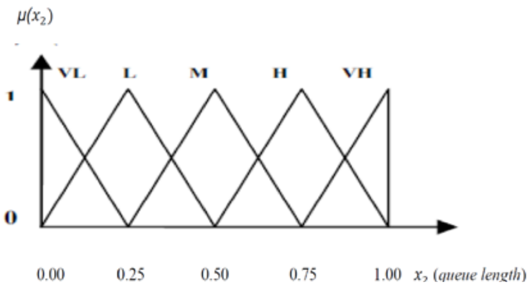

Fig. 3: Membership function for the second input x_2 = queue length or buffer size

the spectrum [Very Low, Low, Middle, High and Very High] and membership degree is in [0.00, 0.25, 0.50, 0.75 and 1.00]. According to membership function for the first input x_1 = delay and the second input x_2 =queue length or buffer size, it was depicted in Fig. 2 and 3, respectively.

Finally, the only output is fuzzy rate or goodness degree that is $y = f(x_1, x_2)$. Fuzzy rules include the High Low, High middle 0.500, 0.625, 0.75, 0.875, 1.000] (Tan, 2011). The fuzzy output rule base is illustrated in

Procedure *FuzzyAcoRouter*

// Let $delay_p$, hop_p and $delay_i^{i+1}$ be the delay of path p , the number of hops of path p and delay seen on passing $node_i$ to $node_{i+1}$ respectively.

Compute:

$$delay_p = \sum_{i=1}^{hop_p - 1} delay_i^{i+1} * f_i(Q_i)$$

// This formula is related to forward ant. If the buffer size is not suitable for queue the algorithm will consider more than one otherwise one for $f_i(Q_i)$. It acts as coefficient.

// Let $ay\_prop_i^{i+1}$, $delay\_proc_i^{i+1}$ and $delay\_trans_i^{i+1}$ be the delay propagation , delay processing and delay transmition from $node_i$ to $node_{i+1}$ repectively

Compute:

$$delay_i^{i+1} = delay\_trans_i^{i+1} + delay\_prop_i^{i+1} + delay\_proc_i^{i+1}$$

// Let Q_{mac}^i be the number of packets waiting on queue in MAC layer , $mean\_delay_{mac}^i$ be the mean delay between enterance and commited transfer of a packet and $delay\_trans_i^{i+1}$ be transmition delay.

Compute:

$$delay\_trans_i^{i+1} = (Q_{mac}^i + 1) mean\_delay_{mac}^i$$

// Let $cur\_delay_{mac}^i$ be the time needed to send packet via $node_i$ and ρ be coefficient whereas $\rho \in$ [0,1].

Compute:

$$mean\_delay_{maci}^i = \rho mean\_delay_{mac}^i + (1-\rho) cur\_delay_{mac}^i$$

// Let $Fuzzy\_Rate_p(t)$ be degree of goodness according to fuzzy base rules , n_f be the number of fuzzy inputs and M be the number of fuzzy base rules.

Compute:

$$Fuzzy\_Rate_p(t) = \frac{\sum_{l=1}^{M} y \prod_{i=1}^{n_f} \mu_{A_i^l(x_i)}}{\sum_{l=1}^{M} \prod_{i=1}^{n_f} \mu_{A_i^l(x_i)}}$$

// Let $Fuzzy\_Rate_{j,d}^n(t)$ be the path goodness by passing from n to d via $node_j$

Compute:

$$Fuzzy\_Rate_{j,d}^n(t) = (1-\rho) Fuzzy\_Rate_{j,d}^n(t-1) + \rho Fuzzy\_Rate_{j,d}^n(t-1)$$

// Let l be all neighbours of n and calculate the selection probabilistic for all path via $node_n$

// It is pertained to backward ant and lookup table will be updated for $node_n$ with the value of $P_{j,d}^n(t)$ by forward ant.

Compute:

$$P_{j,d}^n(t) = \frac{\left[\frac{1}{Fuzzy\_Rate_{j,d}^n(t)}\right]}{\sum_{l \in Neighbour(n)} \left[\frac{1}{Fuzzy\_Rate_{l,d}^n(t)}\right]}$$

Select Max $P_{j,d}^n(t)$ for routing the packet as next hop.

End{ *FuzzyAcoRouting* }

Fig. 4: Our proposed algorithm as fuzzy ACO router

Table 1: The fuzzy output (y) rule base

Row (x_1) column x_2	Very low	Low	Middle	High	Very high
Very low	Middlest	Low high	Low high	Low middle	Lowest
Low	0.500	0.250	0.250	0.125	0.000
Middle	0.500	0.500	0.375	0.125	0.125
High	0.750	0.375	0.375	0.250	0.125
Very high	1.000	0.875	0.625	0.375	0.125

Table 2: Result of Algorithms Execution with Constant Bit Rate (CBR) Traffics

Row (Metric) column (Algorithm)	Mean packet loss (%)	Jitter (%)	Mean through put (%)	Mean delay (%) (sec)
BF	20	33	129 kbps	4.2
OSPF	19	24	160 kbps	3.5
Aco router	13	17	205 kbps	1.9
Fuzzy aco router	4	3	225 kbps	0.6

Table 3: Result of Algorithms Execution with Variable Bit Rate (VBR) Traffics

Row (Metric) column (Algorithm)	Mean packet loss (%)	Jitter (%)	Mean through put (%)	Mean delay (%) (sec)
BF	40	56	110 kbps	5.02
OSPF	20	47	143 kbps	4017
Aco router	26	30	323 kbps	3.4
Fuzzy aco router	8	15	608 kbps	1.02

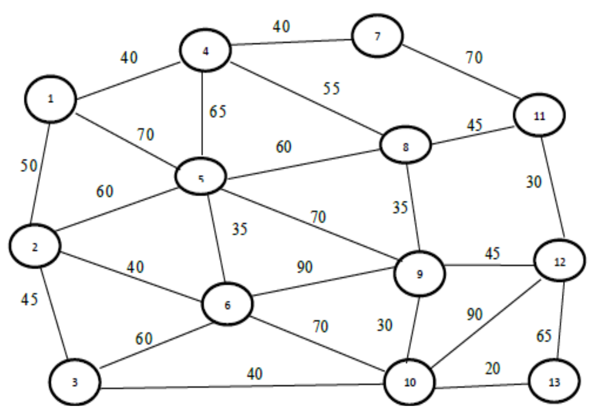

Fig. 5: Example of network topology

Table 1. The concept of FuzzyAcoRouter was inspired from (Mirabedini and Teshnehlab, 2007b), we propose our algorithm with changes as can be seen in Fig. 4.

RESULTS

Assume that *G* is a graph shown as a zone of nodes displayed in Fig. 5. Each node is a computer or a router and each edge (i, j) is a connection between $node_i$ to $node_j$ and the number on the edge is considered for approximate connection cost. Graph *G* has 13 nodes and every node has capacity of 200 packets at most. Suppose that nodes labeled 1, 2 and 3 are producers or source nodes and nodes labeled 11, 12 and 13 are consumers or destination nodes and the rest nodes are intermediate nodes. Our proposed algorithm will be executed in two modes; Constant Bit Rate (CBR) and Variable Bit Rate (VBR). In the first case each packet is generated with 0.005 second rate and in the latter case each packet is generated with variation rate at most 0.005 second. The algorithm objective is to satisfy QOS parameters. Execution implies that our algorithm has high performance in comparison with BF, OSPF and AcoRouter on each QOS parameters. As can be seen in Table 2 and Table 3, columns are QOS parameters and rows are algorithms and finally the best result is highlighted.

CONCLUSION

In this study, we have proposed an optimal algorithm for packet routing based on mixing of fuzzy control system and swarm intelligence like ACO. The execution result implies that FuzzyAcoRouter has the best outcome in comparison with other standard protocols. By using fuzzy control system and different intelligent algorithm, we will have more flexibility for packet routing in network diverse circumstances especially in satisfying QOS criteria. It will be heralded that swarm intelligent methods must be used in all network protocols in future.

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