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A hybrid computing approach to improve convergence time for scalable network

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Abstract. Border Gateway Protocol (BGP) is a widely used routing protocol in the new era for the inter-communication between the multiple autonomous systems and it has been largely on the internet in all categories of the scalable network. In the event of failure, the BGP as an inter-domain routing protocol shows slow convergence, which results in high considerable delay in several internet/web applications. The minimum route advertisement interval (MRAI) timers are mostly used by network operators to reduce the issues occurring at the time of increasing convergence time. Many researchers have been working on variation in MRAI timer and effect of it on scalability and network convergence. The increasing size of a network leads to an increase in the value of MRAI timers. Hence, keeping the value of MRAI timers optimum results in reducing the issue of slow convergence for the scalable network. The proposed system (FAPSO) reduces the problem of convergence time by incorporating fuzzy logic into Particle Swarm Optimization (PSO) algorithm for the scalable network. In comparison with the static value of MRAI timer i.e., 30 s, FAPSO is a suitable algorithm that gives the optimal value of convergence time for the scalable network.

Keywords. Convergence time; MRAI; FAPSO; inter-domain routing.

1. Introduction

BGP (Border Gateway Protocol) is the backbone routing protocol of the internet used in inter-domain routing. In the internet, BGP is used to establish and maintain the connections between the autonomous systems. Many researchers have widely studied the BGP convergence property as BGP has unreasonable behaviour with respect to convergence [1–3] and [4]. BGP has different behaviour and working compared with other routing protocols as by using various routing policies it manages the routing paths effectively and more efficiently. The network topology is used to create routing information. This information is most essential to improve the performance of a network, routing policies and topology design. Fast convergence of a network can help to improve the fast rerouting, minimize end to end delay, and reduce packet losses. Network faults such as node/link failure or route flapping have a latency ranging from several seconds to several minutes. Such condition leads to loss of packets which in turn affect the network performance. Convergence time of a network increases because of failure and flapping in the network. Figure 1 shows the BGP Autonomous System (AS). It represents two autonomous systems AS1 and AS2, communicating with each other with the help of BGP (Border Gateway Protocol) protocol. Communication within the autonomous system is handled using the intra-domain routing protocol like RIP, EIGRP, and OSPF, etc.

BGP is the enhanced version of the EGP protocol. Currently, BGP version 4 is being used for communication. BGP monitors the routing table and finds the best path along with all alternate paths [5]. As there are multiple paths available in the network, so BGP requires more time to go through all the paths. In the Internetwork, failure occurs frequently and existing protocols during this period require a large amount of time to recover from failure, which increases the time required to converge. Convergence time is the amount of time needed for a network to reroute the packets after a node or route failure. BGP routing protocol considered this time to be the most important metric. Several researchers significantly carried out the work on BGP convergence time and it is considered to be slow [6]. The reason for slow convergence is that any failure happened in the global internet quickly exchange the update messages between BGP peers while exploring the new path. Convergence time is defined as the time required

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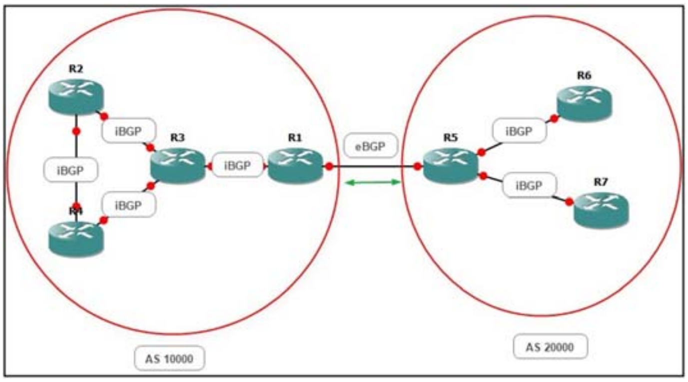

Figure 1. Autonomous system.

for all the routers available in the network to become updated with new, disappeared routes, or changed routes. Convergence optimization can be done by correctly using the minimum route advertisement interval (MRAI) timer for various network scenarios. Since MRAI is one of the parameters that affect network convergence time, we simulated and measured convergence times using NS2 simulator that supports discrete event simulation. We have done the simulations on various scenarios having 50, 60, 70, 80, 90, and 100, etc. numbers of nodes.

We have considered variable MRAI values to test the performance of BGP. The Variable MRAI timer value causes the variation in the number of update messages, traffic, routing table entries, etc. The convergence time of a network is highly affected by different settings of MRAI timers. The convergence performance and the BGP messages are also greatly affected by the timer settings. In this paper, we explore this influence by considering different network scenarios. The convergence time depends upon the network scenarios (topology) which were shown in the simulation. Finally, the topologies were manipulated by including a large number of autonomous systems (ASs) for checking whether the convergence time deviates in respect of network size or not. In the network, 32 ASs are used for different scenarios. We configured and executed various scenarios for different network topologies of nodes ranging from 50–100.

When the impact of the MRAI timer was examined, it shows that MRAI value controls the count of update messages. If the count of update messages is more, this converges all the routers with updated information. Due to this update messages traffic in the network goes on increasing which unnecessarily creates complexity in a real-time network. Bigger the value of MRAI timer wide is the spread of ghost information in the network. This happens because nodes do not converge quickly after the instability (node or link failure) happened in the network. This eventually raises the number of updates. Until the timer lapses, the ghost information spreads in the network; it unnecessarily increases traffic, which results in more failures and instabilities. Such ghost information creates interrupt in the smooth working of convergence in both fail over and fail down situation [1]. With this ghost information, the network goes into an unstable state. To improve the stability Bremler-Barr *et al* [7] modified the existing BGP protocol by adding ghost flushing rate and rule.

Section 2 describes the research work done by several researchers in the field of BGP convergence time. In section 3 research methodology is given regarding FAPSO Algorithm. The simulation and results based on analysis are shown in section 4. Finally, section 5 discusses the conclusion and future scope of the research work.

2. Literature survey

Network convergence is one of the utmost issues in frequently modifying network scenario (topology). High convergence results in dropping of packets, which unnecessarily rises the network delay and instability. Recently, many kinds of research have been done on BGP convergence issues.

Researchers have been focusing on it in various ways, trying to understand, resolve and efficiently improve BGP convergence problem. This section discusses the convergence time and network instability work carried out by several researchers. Labovitz *et al* [3, 6] examined that BGP is an inter-domain routing protocol which takes a significant amount of time to converge because of different internet policy and topology. Hassan *et al* [8] proposed BGP based on path-vector (BGP-PV). This technique efficiently improves throughput and reduces network delay. In this mechanism, the path vector selects the path from vector display, later it splits the path and routes the traffic systematically.

The behaviour of a scalable virtual private network (VPN) is studied by Mai and Du [9]. They analyzed that slow convergence and slow route advertisement are the main factors that create a problem in VPN technology. From the experiment, they show that the slow convergence results in more time required for updating the network routers. Alzate and Reyes [10] simulate the working behaviour of different proposals for minimizing the convergence time of a network, such as EPIC or ghost flushing, from medium to large scale topology network with nodes ranging from 40 to 500. Ricardo *et al* [11] proposed a technique to detect BGP slow convergence events from the whole global routing table. From the experiment, it has been observed that the extremity of slow convergence and path exploration varies because of originated prefixes location and path usage period by introducing a path preference inference method. Also, they noticed that BGP takes more time to converge after failure, also for a large-scale network, latency may increase. They observed the processing overhead and MRAI timer at the router during the convergence period and found that larger the size of failure, larger is the convergence time after a failure.

Fabrikant *et al* [12] noticed that even though the default MRAI timer value is 30 s, still many researchers are working to turn down the value of MRAI timer. From the observation authors reached to a conclusion that considering a lower MRAI timer value results in decreasing the convergence time of a network. The authors clarify that the network convergence cannot improve by decrementing MRAI timer, but it may have a bad impact on network convergence process. So, the variations in the MRAI timer may be done carefully.

Schrieck *et al* [13] found out the different factors which affect BGP churn issues.

1. Some inter-domain nodes or links are frequently unstable and failed.
2. If the routes are unavailable then BGP path exploration problem has occurred.
3. MRAI timer and route flap damping (RFD) may also cause BGP churn and convergence time problem.

Elmokashfi *et al* [14] proposed a technique to study BGP churn evolution by considering four different network scenarios. They experimented for around eight years and reached to the conclusion that the duplicate announcement is the major factor that unnecessarily increases the BGP update messages. As the number of update messages rises the network takes more period to converge. Elmokashfi and Dhamdhere [15] developed an approach to know what is the impact of BGP churn in the future network by considering different topologies, policies, and characteristics of a network. From the result, it shows that the numbers of updates are constant for a certain size of topology but up to some extent.

BGP churn report is generated by Huston [16] from 2008 to 2014 and from the observation, he concluded that routing updates remain constant for some years, but as the prefixes increase it increases the update messages during an announcement of the routing table. The Aiabdulkreem *et al* [17] proposed a modified path exploration technique i.e., fight or flight response technique to reduce the convergence time. This was done by ignoring numerous attributes. As a result of this refinement, convergence time has been reduced up to 30%.

BGP Churn Aggregation (CAGG) technique proposed by Wang *et al* [18] tries to reduce BGP path Exploration by gathering several AS routes in one path, without any bad impact on convergence time. To aggregate those paths, CAGG finds the Path Locality explored by a highly active prefix, which reduces the total number of exchange updates. Yu *et al* [19] proposed the idea of alternate paths along with the primary path. In this, if the primary route fails then network is responsible for diverting the traffic immediately on the alternate path. But managing and storing the multiple alternate paths is very complex.

Deshpande *et al* [20] proposed a technique to detect BGP instability. To detect the instability author used BGP update messages as input that received by BGP routers from its neighbour. The input data contain AS route length, AS path distance, which are drawn out from the data every five minutes to show the variation in the topology. To detect the changes, the author used segmentation boundary detection, generalised likelihood ratio test, and boundary position optimisation algorithm.

To reduce the BGP update messages Huston *et al* [21] introduced a technique called path exploration damping. This technique is also used to reduce the average time needed to restore the reachability session.

Mohammad [22] proposed a comparative study for quick rerouting after failure by taking into account different methods like PSL oriented path protection technique, one to one backs up, Fast Reroute, Haskin, 1+1 path protection recovery mechanism, and local rerouting. The performance from the literature study author concludes that 1+1 path protection recovery mechanism shows a reduction in packet losses, but this technique is highly expensive. Rajvir *et al* [23] developed FLD-MRAI technique for distributing the network load, which minimizes routers overhead. The authors concentrate on BGP policies and their impacts on the number of updates and BGP convergence time. This technique is working for normal as well as for high loads. If DoP (degree of preference) chooses the shortest route, then FLD MRAI considers this situation as normal load, and if DoP chooses the longest route then FLD MRAI considers this situation as high load.

Devikar *et al* [24] reviewed distinct complexes occurred during transmission. In the network, convergence time is a critical issue [6]. In [25] author surveyed the various problems having an influence on BGP convergence time. In this article analysis of various approaches and algorithms has been done to enhance the convergence time. Devikar *et al* [26] developed an approach in addition to load balancing for improving network convergence time and to reducing the congestion.

Chen *et al* [27] introduced a numerical approach to evaluate the convergence time by selecting only the essential ingredients in the convergence process. After they described a greedy method that chooses different ASes for progressive SDN, posted with the scheme of decreasing the convergence time of BGP. In [28] Devikar *et al* introduced an approach to examining the impact of convergence time on convergence time and updates. Later they used the particle swarm optimization soft computing technique to improve the convergence time by simulating different scenarios of a network [29].

Manzoor *et al* [30] analysed the performance of BGP protocol on GNS3 and wire shark network simulator. They considered the simple topology consist of 5 Cisco-7200 series routers. From the experimentation, it has been observed that convergence time depends on the number of routers on the selected path. In this 3 routers are available from source to destination and BGP keepalive time set as 60 s. So the convergence time for this scenario is calculated as 180 s. Moubarak *et al* [31] proposed a BGP-NCM (BGP Novel Control Mechanism) for newly updated path. The author has given a penalty time to any new configuration for reducing the continuous update messages. As the update messages are reduced in the network, results in a reduction in convergence time. Muhammad *et al* [32] proposed an approach that uses the centrality metric to place the designated routers in the network. The authors developed a topology analyser to simulate the convergence process. From the experimentation, it has been found that convergence time is reduced by 19% using centrality metric.

Garcia-Martinez and Bagnulo [33] measured the route propagation time of BGP to calculate the convergence time. Route propagation depends on MRAI timer and path diversity. From the analysis, the author concluded that the propagation time for IPv6 is shorter as compared to IPv4. Diogo *et al* [34] proposed an approach that offers the lowest downtime of a network and gives higher network availability. The proposed Continuous Time Markov Chain (CTMC) approach used to obtained better convergence time in the corporate network.

The rest of the section discussed the enhancement in convergence time and scalability in respect of variable MRAI timer.

3. Research methodology

The convergence time can be maximally reduced by keeping the value of MRAI timer optimal without increasing the number of update messages. As we reduced the convergence time, the network is quickly converged with updated information, which results in a reduction in packet losses. The proposed approach incorporates the fuzzy-based approach (filtering approach) with PSO to find the optimal value of the MRAI timer. The methodology is explained in detail in the given section:-

3.1 *Fuzzy logic*

The fuzzy block is used to identify input-output mapping in the form of several input-output data set. Every output is generated by providing two inputs, i.e., Node scenario and variable MRAI values. The output of BGP simulator block is the degree of each node (i.e., number of connected links) and maximum range of that node. This output is given to the fuzzy logic block. The fuzzy system works based on the fuzzy membership function system (MFS). Unlike boolean logic, it is having two values 0 and 1, fuzzy is having multiple values and uses a range of logical values between 1 and 3. In the implementation, we have taken three different MFS values 1, 2, and 3 that represents low, medium, and high data rate respectively. The output of fuzzy logic is variable convergence times for different scenarios. In the implementation we have taken MRAI values from 5–30 s for different scenarios (number of nodes) range from 50–100.

3.2 *Particle swarm optimization (PSO)*

The PSO algorithm pretends the performance of flocking birds. When a set of birds is looking for food in space, the birds don't have an idea about where the food is, however they know how long the food is in every iteration. Therefore, the finest scheme to search a piece of food is, to track the bird who is nearby to the food [12]. The identical framework is used in the algorithm to resolve the optimization problems. The technique shows every sole solution or a particle is a bird in the search area. Every single particle is having fitness values, which are calculated by using the fitness function.

Fitness values= (INIT_MRAI_INTERVAL) * PSO_CONSTANT_C

Where INIT_MRAI_INTERVAL range from 0 to 30 second and PSO_CONSTANT_C having 0.5 as a constant value. If the fuzzy interval value is extended above the MRAI value then we have to reset the fitness value using the above formula. When the group initialisation of random convergence time is finished, searches are revised for the most favourable convergence time. For every repetition, each particle is updated with respect to local best (pbest) and global best value (gbest). Local best value is the value for that specific particle, and global best value is obtained from the population, whichever is best in the scenario. The pbest is the best solution (fitness) that particle has achieved so far, and gbest is the prime solution achieved up till now by one of the solutions in the population. The algorithm identifies that the best value for KEEPALIVE timer is 30 second, and for HOLD time it is 90 second, which balances the relation between traffic and convergence time. In this work, the algorithm identifies the best value is between 1–2 second as an optimal MRAI timer, and it will reduce the convergence time by around 9%.

3.3 *Fuzzy and particle swarm optimization (FAPSO)*

The FAPSO approach states that the optimal MRAI timer is obtained from the experimentation using PSO based fuzzy approach shown in figure 2.

Using this technique we significantly minimize the iterations and improve the lifetime of a network effectively. In every iteration, the node characterize will be unexpected to grasp the optimal value. The membership function value will fluctuate for different value of data rate. The FAPSO technique that uses fuzzy and PSO technology is used to improve the outcomes by quickly converging a network. When the node or links fail down, the MRAI timer is used for controlling the update message announcements. The convergence time in such case can be calculated as n * MRAI, in which n is the longest destination path, which may be total nodes in the network in the worst case.

In the network, after every period of 30 s routing update is done. If any node or link failure occur instantly after the routing updates, then to know the information related to failure nodes or links network needs to wait up to next update. During this waiting period load on failure node or link increases which may lead to packet losses. By making the value of MRAI timer variable we can improve the performance related to packet losses, number of updates, and convergence time for the scalable network.

In our previous work, we have used FMRAI technique which was used to minimize network convergence time. This technique used particle swarm intelligence for optimization. The proposed work incorporates fuzzy logic in PSO. By making such hybridization we got better optimum MRAI timer result. The convergence time of a network is minimized by considering FAPSO approach shown in algorithm 1. We have considered different scenarios in NS2 simulator consists of 50–100 nodes and 20 autonomous systems. The BGP execution is based on BGP-4 specifications. In the scenario, each node is considered as an AS and links having variable delay and similar bandwidth. The algorithm 1 is used to generate dynamic MRAI timer which improves the convergence time of a network.

4. Experiment setup and result analysis

4.1 *Simulation set-up*

We have worked on six scenarios to calculate values of update messages and convergence time. Each scenario is run for different values of MRAI in seconds like 5, 10, 15, 20, 25, and 30. The experimental setup contains various scenarios of 50, 60, 70, 80, 90 and 100 numbers of nodes. Every scenario has 20 ASs, and several routers in the topology considered as a single AS. The simulation is run till all the routers are converged with updated information. To observe the changes in the convergence time, the several link failure scenarios were also added in the simulation. This is carried out by using the failure/recovery module in NS2 simulator. The module drops a link or node at a specific time T1 and recover it at time suppose T2. So, in this period, we have observed the withdrawal as well as advertise messages in the topology. The period between failure and recovery is kept adequate to observe the update messages in the routing table. Keepalive and hold time interval are kept 30 and 90 s respectively. The routing decision in the BGP depends upon the routing policies. From the topology, after failure, the number of updates and convergence time at the router are measured. The simulation parameters are shown in table 1.

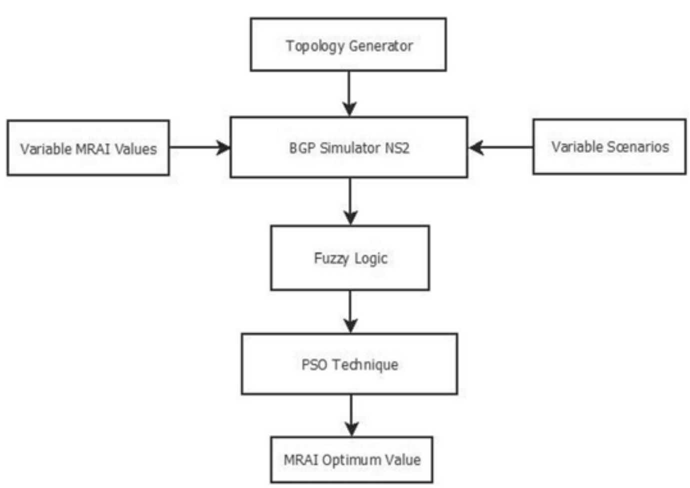

Figure 2. Block diagram of FAPSO approach.

Algorithm 1 Algorithm for FAPSO

```
Step 1. Check autonomous system (AS)
Step 2. Collect all paths to destination
          MRAI_SUM=0;
Step 3. For every connected AS
          {
             Calculate path_delay
             path_delay=path_delay->get_delay(connected_AS_list_.node_id[i]);
             path_Delay is bind with node parameter.
          }
Step 4. For every particle we initialize
          path_delay=0;
          link_delay=0;
          routing_delay=0;
          queuing_delay=0;
Step 5. For every path_delay count calculate
          path_delay = MAX(path_delay, path_delay>delay[j]);
          queuing_delay=MAX(queuing_delay, queue_delay_get_delay(path_delay_->nodeid[j]));
          link_delay = MAX(link_delay,l_delay_ );
          routing_delay=MAX(routing_delay, path_delay->get_delay(connected_as_list_.nodeid[i]));
          Optimal_val= path_delay+ queuing_delay+ link_delay+ routing_delay;
Step 6. Apply fuzzy-based approach
          It allows only those intervals having optimal value less than 30 s.
           if(optimal_val>30)
             {
             Consider this as high interval and low data rate, hence discard the communication.
             }

             • Optimal_val>30, represented as low data rate

             • Optimal_val is in between 10 and 30, represented as moderate data rate

             • Optimal_val<10, represented as high data rate

Step 7. Apply PSO technique
          Initialize best_global=99999999, best_local_optimal=99999999;
          if(Optimal_val< best_local_optimal)
           {
             best_local_optimal= Optimal_val;
           }
          if(best_local_optimal <best_global)
           {
             best_global= best_local_optimal;
           }
Step 8. For every node(i)
          Evaluate V0 and V1 node velocity
            v0 = omega × pso_particle[iter].v[0][i] + constant1 × random1 × (pso_particle[ptr].x[0][i] −
pso_particle[0].x[0][i])+
               constant2 × random2 × (pso_particle[global_ptr].x[0][i] − pso_particle[0].x[0][i]);
            v1 = omega × pso_particle[iter].v[1][i] + constant1 × random1 × (pso_particle[ptr].x[1][i] −
pso_particle[0].x[1][i])+
               constant2 × random2 (pso_particle[global_ptr].x[1][i] − pso_particle[0].x[1][i]);

          Use best_global value and velocity to update node data.

Step 9. Evaluate MRAI value
           nid = get_node
          path_delay = path_delay_->get_delay(nid);
          queuing_delay = queue_delay_.get_delay(nid);
          link_delay = l_delay;
          routing_delay = MAX(routing_delay, path_delay_->get_delay(nid));

Step 10. MRAI_SUM = (path_delay + routing_delay + queuing_delay + link_delay);
Step 11. if(MRAI_SUM >= MRAI_MAX)
          {
             MRAI_SUM = Default_MRAI;
             return MRAI_SUM;
          }
          else{
             return MRAI_SUM;
          }
```

4.2 *Result and discussion*

4.2a *MRAI vs convergence time and updates:* The change in convergence time and evaluation of optimum MRAI value with respect to MRAI timer for FMRAI and FAPSO approach is shown in tables 2 and 3. From the experimental result, it has been observed that the value of convergence time and optimum MRAI are proportional to MRAI timer. As we increase the value of the MRAI timer, correspondingly it will increase the value of convergence time. The convergence time is calculated for different MRAI values from 5–30 second for 50–100 nodes. Result

Table 1. Simulation attributes or parameters.

Area	1200m × 1000m
MRAI timer (second)	5, 10, 15, 20, 25, 30
Node Count	50, 60, 70, 80, 90, 100
Automomous systems	20
Gateways	10
Packet length	512, 1024, 2048
Buffer length (queue)	50 Packets
Bandwidth	10 Mbps
Delay	2 ms
Communication range	40

also shows that as we increase the nodes from 60 to 100 there is a small change in the value of convergence time. So with FAPSO technique we also reduce the scalability issue.

Figure 3 shows the relation between the update messages (events) with respect to MRAI values for FMRAI and FAPSO technique. The number of updates is inversely proportional to the MRAI values. From the experiment, it has been observed that more traffic is generated for a lower value of MRAI timer. This happens because, for a lower value of MRAI, the routes are discovered rapidly after links or node failure which results in a reduction in packet losses. The BGP updates are used to notify the neighbouring routers. BGP protocol goes through the routing table and finds out the next suitable path from the table. So, for improvement in network convergence and performance, there is a need to keep a minimum value of MRAI timer. table 3 shows the optimal MRAI timer for different MRAI values from 5–30 s in a scalable network.

4.2b *Node vs packet delivery ratio (PDR):* Analysis of routing protocols is done based on different performance metric like PDR, throughput, routing overhead, and network delay. Figure 4 shows the variation in PDR for different network scenarios i.e., the number of nodes. From the result analysis it has been observed that with an increase in the number of nodes, we are getting low PDR value for default MRAI. FAPSO technique returns better result than our previous FMRAI work and achieves a maximum value of PDR around 97% for 50 nodes. But if we scale the network, after some extend the PDR value reduces below 90% because the number of paths reaching to the destination goes on increases and it may happen congestion at the receiver end.

PDR=received_packets * 100/generated_packet.

Table 3 elaborates about different values of packet delivery ratio for the variable number of nodes.

4.2c *Number of nodes vs throughput:* Throughput is the average number of bits that are transmitted successfully per second shown in table 3. For increasing the number of nodes, this QoS parameter analyzes the interference increased by the number of nodes shown in figure 5. Throughput usually depends upon several aspects of a network such as scheduling strategy, power control, routing schemes, acknowledgement, packet collision, obstructions between nodes, and network topology. The key for better throughput is network synchronization. Packet drop effect is directly related to the throughput. Lack of route or network congestion leads to the packet drop. Throughput is the ratio of number of packets received or sum of packet sizes are calculated at every interval to the data transmission period. From the experimentation, it has been observed that FAPSO is having lower convergence time so that all the node are converged with updated information. Because of the fast convergence process packet drop ratio is reduced by FAPSO approach which in turn increases the number of packet transmission per second (i.e., increase throughput).

4.2d *Number of node vs delay:* It is measured as the time interval between messages queued for transmission and the last bit received by the receiver. From the experimental result it has been shown that as the number of nodes is increased, the delay also increases. Suppose no node is available or link fails, the time required for packet transmission increases i.e., delay increases shown in figure 6. If the number of nodes increases this will gives better opportunities to search a suitable path for packet transmission. Table 3 shows for the scalable network, the delay is lower.

The average delay is calculated based on sending and receiving time of packet and it is given by:

Table 2. Optimal BGP MRAI timer for the variable MRAI values in different scenarios.

No. of nodes	MRAI5		MRAI10		MRAI15		MRAI20		MRAI25		MRAI30	
	FMRAI	FAPSO	FMRAI	FAPSO	FMRAI	FAPSO	FMRAI	FAPSO	FMRAI	FAPSO	FMRAI	FAPSO
50	1.00619	1.00690	1.03181	1.02137	1.03522	1.03370	1.02428	1.02327	1.22242	1.03352	1.12179	1.12614
60	1.00782	1.00360	1.00707	1.00353	1.0066	1.38838	1.00643	1.00379	1.00647	1.00359	1.80286	1.00365
70	1.00504	1.00418	1.00670	1.00345	1.0062	1.00350	1.00555	1.00439	1.00682	1.00345	1.00771	1.00424
80	1.09536	1.08312	1.00439	1.08623	1.0825	1.00380	1.00484	1.09609	1.20448	1.00363	1.00440	1.00360
90	1.00679	1.00338	1.07655	1.00331	1.13138	1.00330	1.00553	1.00331	1.00658	1.00333	1.00681	1.00336
100	1.00804	1.00375	1.00944	1.00331	1.00894	1.00354	1.01062	1.00437	1.59332	1.00366	1.00905	1.00404

Table 3. Number of node vs PDR, delay, and throughput.

Number of nodes	Packet delivery ratio using FMRAI	Packet delivery ratio using FAPSO	Delay using FMRAI	Delay using FAPSO	Throughput using FMRAI	Throughput using FAPSO
50	94.99	97.43	0.54361	0.34554	480239	492564
60	94.74	98.92	0.59363	0.402744	416942	419662
70	93.105	97.1448	0.39235	0.280598	339355	342587
80	92.376	96.1161	0.54367	0.366363	330920	339812
90	94.78	95.8597	0.41239	0.29666	392799	400046
100	91.57	93.3535	0.49959	0.300134	348061	351649

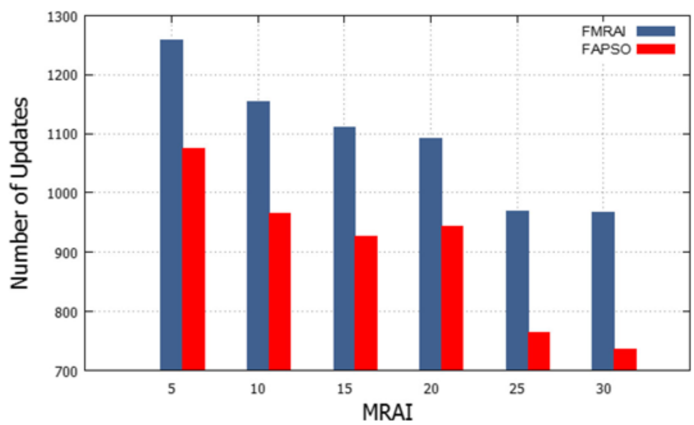

Figure 3. MRAI vs number of updates.

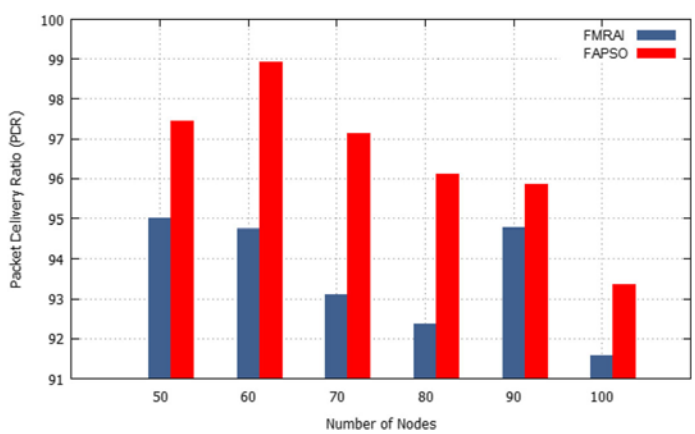

Figure 4. Nodes vs packet delivery ratio.

j = Sequence number of Packet
cnt = total number of packets
Net_Delay[j] = received_time[j] − send_time[j]
Net_Delay[j] is the combination of routing_delay[j] and processing_delay[j].
Total_delay = Total_delay + Net_Delay[j]
Avg_delay = Total_delay/cnt.

4.2e *Number of nodes vs convergence time:* Figure 7 shows the convergence time for FMRAI and FAPSO technique for a scalable network. Experimental results show that with an increase in the number of nodes gradually it increases the convergence time. Table 3 shows that the FAPSO technique performs better than our previous FMRAI technique [28].

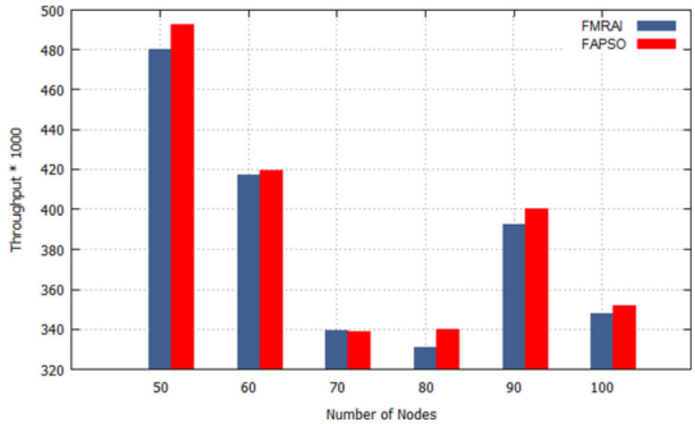

Figure 5. Nodes vs throughput.

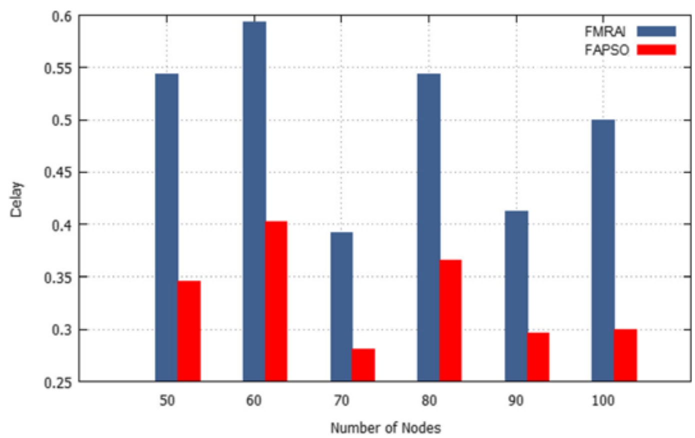

Figure 6. Nodes vs delay.

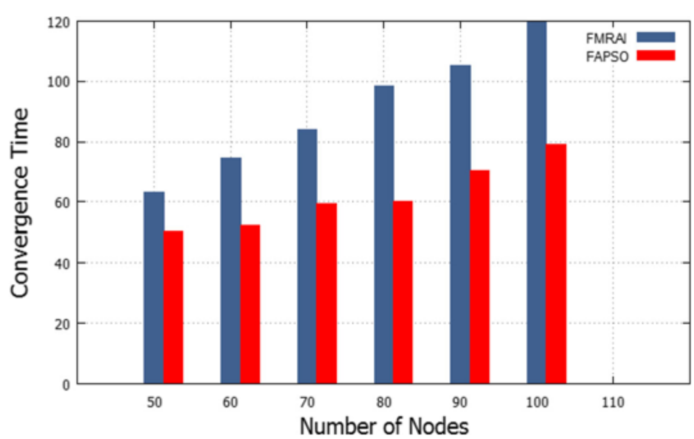

Figure 7. Number of node vs convergence time.

5. Conclusion

In the new era, convergence time is the most important parameter used to estimate network performance. The proposed work optimised the MRAI timer by using the FAPSO technique and compares the results with FMRAI technique. From the experimental result, it has been observed that FAPSO technique gives better optimised MRAI timer than FMRAI. As we have optimised the MRAI timer, it reduces the convergence time by around 9%–10%, required to reach the updated information in the scalable network. The result analysis shows that for the scalable network this technique also performs well. The proposed FAPSO technique is also used to improve different parameters like packet delivery ratio, scalability, network delay and throughput for different network scenarios i.e., the number of nodes.

In future, we will classify and update messages in three different categories namely obsolete, reusable, and newly added routes using hybrid computing approach.

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