

FA-LAR: an efficient flow aware based load adaptive routing scheme for optical communication networks

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Abstract

Routing Protocols have been proposed to enable the network to identify and suggest various routes to number of demanded flows. In the Flow-Aware Network Models, the routes are identified and selected with the help of Flow Tables or Flow Identifiers that proposed by Flow Aggregation Mechanism. That is, users can define a Flow Aggregation Model to suggest routes depend on their defined-demanded flows and this model effectively handles many flows, which helps core routers to profit aggregate routing. This is an efficient and effective approach to identify a best route to achieve required performance. It is noted from the literature survey that the Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) was proposed for achieving higher Network performance through multipath solutions. This FAMTAR Model was implemented and studied thoroughly. From the experimental results, it was noticed that this model unable to i. detect and manage bulk flow, ii. Control Traffic Loss and iii. Maintain Deviation of Links Load against Traffic Load. To address the above mentioned issues, this research work is proposed an efficient Flow-Aware based Load Adaptive Routing (FA-LAR). This model is developed and implemented in ns3 and the simulation results are analysed carefully. From the experimental results, it is noticed that the proposed Model, FA-LAR is performing well as compared with the existing FAMTAR in terms of Queueing Delay, Throughput, Power Consumption (Energy Dissipation), and Load Deviation. It is also noticed that the proposed model unable to achieve higher Throughput for Low Load.

Keywords: Flow-Aware Network Models; Flow-Aware Multi-Topology Adaptive Routing; Flow-Aware Based Load Adaptive Routing; Load Balancing; Routing Protocols.

1. Introduction

Flow Routing Schemes have used to analyse and evaluate Network Routes, which will help to deliver Packets with the required QoS. It is helping to achieve Load Balancing on high speed communication networks. The Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) Routing Scheme [1-5] is the Multipath Routing Capabilities, which is designed to work on the concept of Flows.

It is capable of identifying different paths between Source and Destination. As it has identified multi paths, whenever the first route gets congested and unable to achieve QoS, it uses the alternate path, which already identified to deliver packets with the required QoS to Destination. That is the suspended primary path will be used later when its available bandwidth satisfied to achieve QoS.

Though it is observed as the best idea to achieve required QoS, providing Scalability is considered as the major challenge as large networks needed to handle millions of flows at a time at each Router. That is if Router involves handling all these details of Flows, it will constitute delay and it will increase Processing and Response Time as well. The large memory has to allocate for the same which will degrade Routers performance further.

From the literature survey, it was noticed that a few popular Flow based Routing Techniques were proposed recently[1], [8], [9],

[10] and they are: i. Software-Defined Networks (SDN), ii. Fast Flow Table Aggregation, iii. Local Fast Reroute (LFR) Techniques.

These Techniques were studied thoroughly and noted that it will not support for Flow Aggregation Mechanism, as these schemes did not have Central Controller.

Flow Aggregation Mechanism was proposed for FAMTAR (FAMF) [1], [2], [6], [7] and this is to address the above-mentioned issue and it noticed that this scheme was reducing the flows entries. It was noticed that the flows entries did not depend on additional signalling between end-nodes.

The remaining sections are organized as follows. The section 2 describes the various Flow-Aware Adaptive Routing Schemes such as Load Adaptive Sequence Arrangement (LASA) with Fixed Minimal Transmission Time (FMT) and Flow-Aware Multi-Topology Adaptive Routing (FAMTAR). In section 3, the identified problems of the existing model FAMTAR is described. In section 4, the proposed model, Flow Aware-Load Adaptive Routing (FA-LAR) is discussed. Section 5 presents the performance analysis of the proposed Flow Aware-Load Adaptive Routing (FA-LAR) and results findings are concluded in Section 6.

2. Flow-aware adaptive routing schemes

This research works described and reviewed recently proposed two popular Adaptive Routing Schemes namely i. Load Adaptive Sequence Arrangement-Fixed Minimal Transmission Time (LASA-FMT) [1-2] and ii. Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) [1-2] in this section.

2.1. Load adaptive sequence arrangement (LASA) with fixed minimal transmission time (FMT)

The Energy Efficient based Load Adaptive Polling Sequence Arrangement (LASA) Scheme was proposed by Yunxin Lv and ET. al. [3-16]. It is jointly working with Fixed Minimal Transmission Time (FMT) and this LASA-FMT is a Multi-Point Control Protocol.

From the literature survey, it was noticed that the Optical Access Network, the Optical Line Terminal (OLT) is responsible for managing the communication performances of the Optical Network Unit (ONU). This is used to schedule the resources to reduce sleeping time as well as communication delay. It is responsible to avoid Traffic Collision.

The LASA was executed in Optical Line Terminal (OLT) [1], [30-33] and Optical Network Unit (ONU) is shown in the Figure 1 and Figure 2 respectively. As shown in the Figure 1, the Optical Line Terminal (OLT) will collect messages from Optical Network Unit (ONU) to understand the required bandwidth for the communication. The detailed procedure of LASA is executed in Optical Line Terminal (OLT) is shown in the Figure 2.

The Polling Sequence Arrangement (PSA) was demonstrated by processing a message label, which included in report message. That was allocating each ONU an uneven idle time rather [30-33].

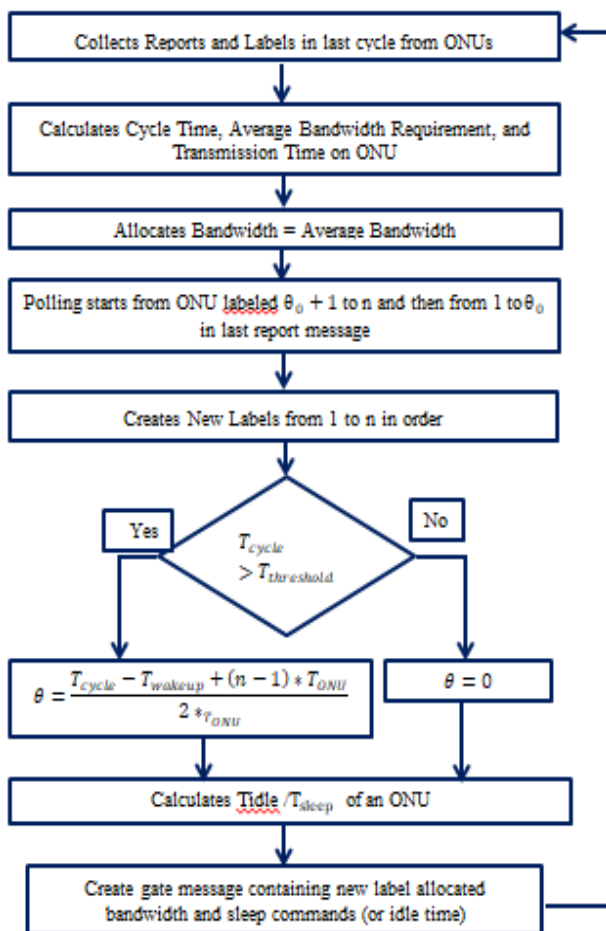


Fig. 1: LASA Scheme Executed at Optical Line Terminal (OLT).

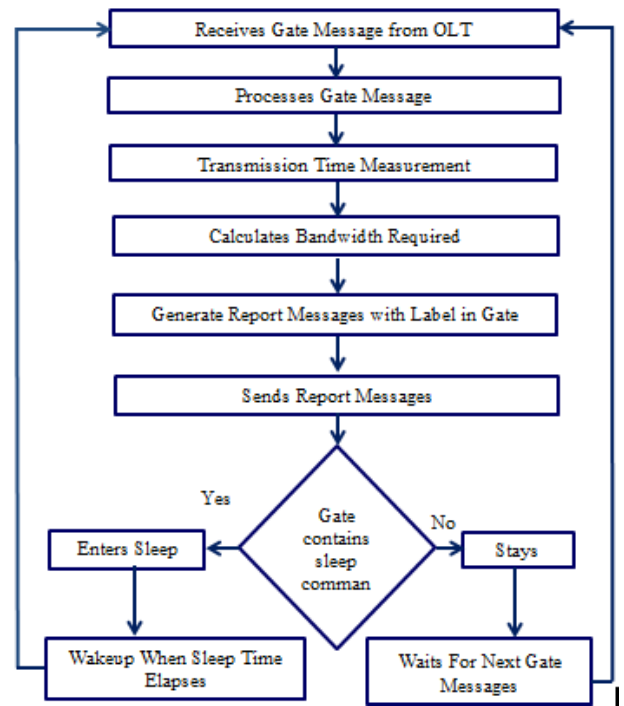


Fig. 2: LASA Scheme Executed at Optical Network Units (ONU).

The Load Adaptive Sequence Arrangement (LASA) was proposed with the idea of Optical Network Units. This was working based on polling sequence in accordance with traffic load. The main objective of this model was to improve energy efficiency. The Polling Sequence Arrangement can be performed through label which can be executed by adding report message.

When the polling sequence is changed, the ONUs will allocate longer idle times which will activate to sleep longer time as well. It was noticed from the literature survey that the polling sequence arrangement affect the energy efficiency of the network [1], [2], [19-24].

To achieve energy efficiency under a low-load network, the LASA was jointly working with the fixed minimal transmission time (FMT) and this was called as the LASA-FMT scheme.

From the Literature survey, it was noticed that the LASA-FMT is suitable for Energy Efficient Routing. However, it fails to achieve Queuing Delay, Throughput and Load Balancing. It doesn't focus to establish shortest path to make communication.

2.2. Flow-aware multi-topology adaptive routing (FAMTAR)

Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) is a Dynamic Multipath Adaptive Routing scheme introduced by Jerzy Domzal[3]. It works purely based on flows. FAMTAR is called adaptive because it works with all routing protocols to establish communication between source and destination with shortest path. This shortest path will be used for all the data transmission until it found congestion. If congestion occurs, the optimal path can change as per the status of congestion indication. During the bottleneck of congestion the new flows are redirected to travel via new path, and old flow will be permitted to travel in the same link. So, FAMTAR is taking responsibility to identify the optimal paths and also identify new path when bottleneck arises.

To attain this, a FAMTAR router retains Flow Forwarding Table (FFT) along with routing table. For each flow, the respective FFT entry shows that packet routes that have to forward the current flow. It is extracted from the present routing table when the first packet appears in the FFT. The Flow Forwarding Table is facilitating to identify the packet routing mechanism. Based on the FFT, the outgoing connections are identified and flow will be redirected if necessary. The FFT remains static and it will not change even the routing table entries are changed.

If congestion is identified at any one of the links, then the corresponding router will increase the link cost by higher value. Once the link assigned with higher value then it is considered to be a congested link. The updated cost make change at the routing protocol, which broadcast the information in all the links. Upon receiving this information, the routers calculate new link to manage and avoid congested links. The newly calculated links are updated in the routing table [14-17].

This change is applicable for new flows alone. The flows, which are already in active state, will follow the same route as per the flow state stored in the FFT. Therefore, the congested links will not stop the packet flows even as the route were identified as congestion earlier. The actual costs of all links are restored when the congestion on the link stops. FAMTAR needed routers to overview links and to identify congestion on those links. It uses congestion indicator like Packet Queuing Delay, Link Load, and Queue Occupancy etc. [1], [2], [25]-[29].

If the link or node failure occurs, the active flows along with identifiers registered to the FFT, are still uses the older route stored in the FFT. As a result, the active flows are possible to route through to the failed links. This problem was identified and solved in [4] by introducing a Time To Live based scheme so that it can be detected failure links and it is also will find routing loops.

2.3. Flow aggregation mechanism for FAMTAR

The FAMF [11-13] called as Flow Aggregation Mechanism for FAMTAR assumes that only edge routers maintains flow list in autonomous systems. It means that there are not available in the internal routers. The Edge Routers can find aggregation link with the various flows details. The Edge routers which designed for FAMF needed to maintain the following two flow lists. They are,

- A Flow Forwarding Table (FFT) contains parameters of Flow Identifier (flow_id), Aggregate Identifier (aggr_id), Output Interface (int_id) and last packet arriving time (timestamp)
- An Aggregation Table (AT), which contains parameters of aggregate identifier (aggr_id), and output interface (int_id).

FFT is proposed to process packets, which did not possess aggr_id that are coming to the domain. The Aggregation Table was used to process packets, which are previously have aggr_id. The core routers need only ATs and it need not have FFTs. The prime objective of this proposed scheme is to establish the entire flow routes at an edge router of a Network system, which may be autonomous one. The route can identify by routing protocols based on information that collected. In OSPF, all routers maintain the link-state database. After each update, the routers execute Dijkstra algorithm is used to find the shortest path in a network.

It focuses outgoing flows and it knows the exact path to the destination node. The route is denoted by the identifier (aggr_id) and is updated to FFT. This is too added to Aggregation Table with output id interface for the selected path. It is observed that core routers are maintaining at ATs. The aggr_id is a group of routers IDs which are on the path between edge routers' and destination. Traffic Class field or a 20-bit Label Flow field can be used as a aggr_id for IPv6. The working procedure of FAMF [2] is given below. This research work didn't modify or rephrase the functionalities of FAMF proposed by Jerzy Domżał et. al. [2].

FAMF ensures entries are purely based on the network i.e total lists of entries maintained by core nodes are restricted to possible routes available in the network. The entries in the table has to be lesser than that of entries served by the router [18-20].

The FAMF Model is considered as complex one as compared to FAMTAR. However, the complexity level depends on the type of node available in the network. In the edge routers, more operations that are complex needed to identify the first packet of a flow. To add new registration to the FFT, it is also wanted to calculate aggr_id and add it to the AT. The computational calculations in this area are even more important in core routers, when it differs between flows and aggregates are higher than in edge routers. The

replacement of FFTs with ATs, the operational and computational complexity of core routers will minimize [21-24].

*Check the packet whether it contains the aggr_id (X) or nor
The router acts as follows based on with or without aggr_id status of Packets*

For each packet without aggr_id, (entering a domain):

Step 1 : The router checks whether the flow ID associated with the packet exists in FFT.(A).

Step 2 : If the flow ID is in the FFT:

- The router reads the aggr_id from the FFT and also reads the output interface (int_id)(B).
- The router writes the aggr_id to the packet (C).
- The router updates the timestamp field by putting the current timestamp (D).
- The router forwards the packet to the output interface that was read from the FFT (E).

Step 3 : If the flow ID is not in the FFT:

- The router determines the path to the end of domain (to the destination node or the last node in domain, if the destination node is outside domain).
- The path is represented as a list of nodes (F).
- The router determines the aggr_id and also reads the output interface for packets (G).
- The router creates a new entry in the FFT and puts the designated values in the appropriate fields (H).
- The router forwards the packet to the designated output interface (I).

For each packet which already has aggr_id:

Step 1 : The router checks whether the aggr_id read from the packet is in the AT (J).

Step 2 : If the route appears in the AT:

- The router reads the int_id from the AT (K).
- The router forwards the packet to the next node based on the int_id (M).

Step 3 : If the route does not appear in the AT:

- The router determines the int_id (N).
- The router adds an entry in the AT (O).
- The router forwards the packet to the next node based on the int_id (M).

For each packet leaving the domain:

Step 1 : The router deletes the aggr_id from the IP header.

Step 2 : The router sends the packet outside the domain according to the operation of a traditional IP network.

3. Identified problem

As each one of us using Internet, Researchers are focusing Flow-Aware Routing and Topology Aware Routing as well. They developed a few Network Models for the same. Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) is considered as the best Routing Approach to improve the Network Performance. Flow Aggregation Mechanism was proposed to FAMTAR to improve the Network performance. From the literature survey and experimental Results, it was noticed that the Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) is performed the Flow Aggregation by Edge Nodes of Network. To achieve better performance in terms of Deviation and Maximize Network Life Time and to predict and detect Interval Heavy Flow or Bulk Flow, the better Flow Aggregation mechanism is needed.

To address the above mentioned demands, this work is proposed an efficient Flow Aware-Load Adaptive Routing (FA-LAR) to address the same.

4. Proposed model flow aware-load adaptive routing (FA-LAR)

The proposed Flow-Aware Load Adaptive Routing Scheme is developed based on the models of both Load Adaptive Sequence Arrangement (LASA) and Flow-Aware Multi-Topology Adaptive Routing (FAMTAR). This is the hybrid mechanism, which developed to address Load Deviation, Energy Consumption to Maximize Network Life Time and to predict and detect Interval Heavy Flow or Bulk Flow. The flow chart of the proposed Flow-Aware Load Adaptive Routing Scheme was as shown in the Fig. 3.

As shown in the Fig. 3, the proposed model has report message with Label to confirm Polling Sequence. This is used to save energy by preventing inefficient sequence arrangement. In other words, the proposed scheme provides sleeping time when route is congested and it can increase average cycle time. This facilitates for optimizing the performance of energy consumption under low-traffic and high traffic as well.

As per the traffic load, the scheme can be improved the energy efficiency of networks. The polling sequence arrangement is executing through label process which was added in report message as described earlier. While polling sequence was changed, the proposed model will allocate lengthier idle times will sleep longer. This facilitates significant effect on the energy efficiency of the network. This Load Adaptive Sequence Model forward Packets to Flow Aggregation Scheme which aggregates flows to improve Network performance in terms of Throughput, Delay and Load

Deviation. The detailed procedure of the proposed model is described in the Fig.3 as follows.

4.1. Working procedure and operations of flow aware-load adaptive routing FA-LAR)

The procedure and operations of the proposed hybrid FA-LAR is narrated in the Fig. 3. This proposed mechanism is an intelligent method that establishing the all possible routes that aggregates flow through edge routers. The route can be identified and selected based on the collected information with the help of the proposed model, which described below.

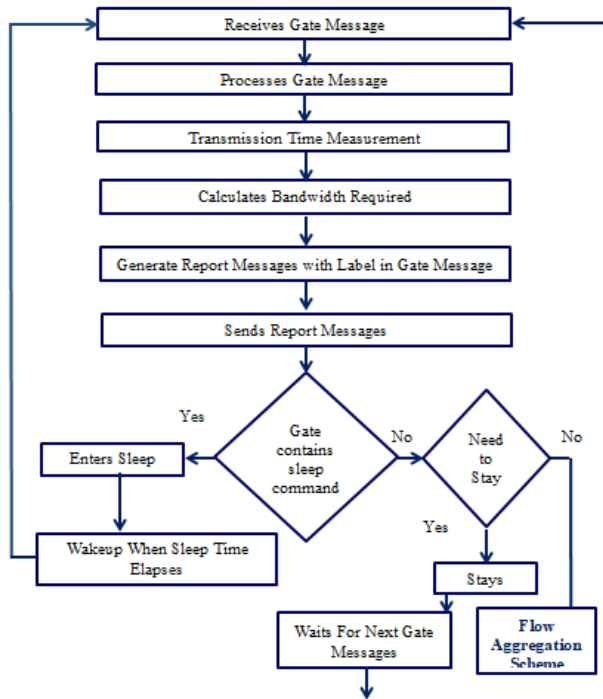


Fig. 3: FA-LAR Scheme.

5. Performance analysis

This research work is implemented the Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) and the proposed Flow Aware-Load Adaptive Routing (FA-LAR) Schemes in ns3. For each flow, 0.1 GB is reserved. We created 100 x 100 Nodes Clusters with a fixed Topology and introduced 1ms delay. The simulation was carried out for 350 seconds.

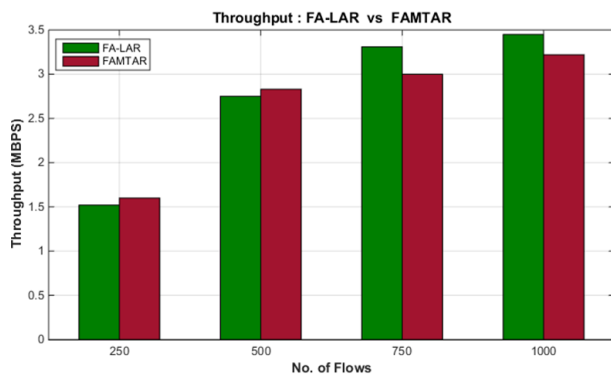


Fig. 4: Throughput Analysis of the Proposed FA-LAR.

The proposed Flow Aware-Load Adaptive Routing (FA-LAR) is studied thoroughly and analyzed in terms of Throughput, Queuing Delay, Power Consumption (Energy Dissipation), and Load Deviation.

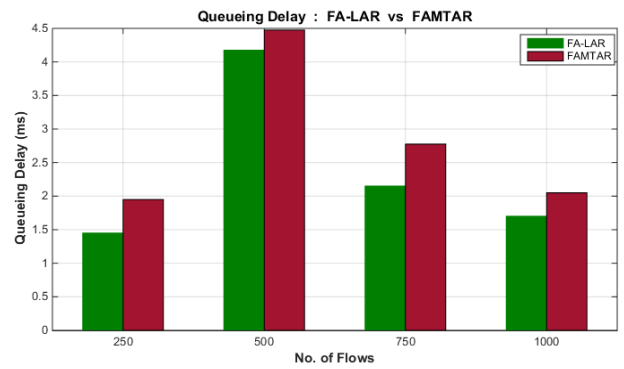


Fig. 5: Queuing Delay Analysis of the Proposed FA-LAR.

The experimental results of the simulation are shown at the Figures Fig. 4 to Fig. 7. As shown in the Fig. 4, the proposed FA-LAR is achieving higher Throughput as compared with the existing FAMTAR for heavy volume of Networks. That is the FA-LAR is achieving higher Throughput for more than 500 Flows. At the same time, the proposed model unable to provide higher Throughput for less than 500 Flows. This is happened because the proposed model focussing Traffic Loss and Maintain Deviation of Links Load against Traffic Load as well.

As this research work proposed an efficient Flow-Aware mechanism, it handles Traffic Congestion situation efficiently and effectively that facilitate to achieve lesser Queuing Delay as compared with Flow Aware-Load Adaptive Routing (FA-LAR) Scheme, which is shown in the Fig. 5.

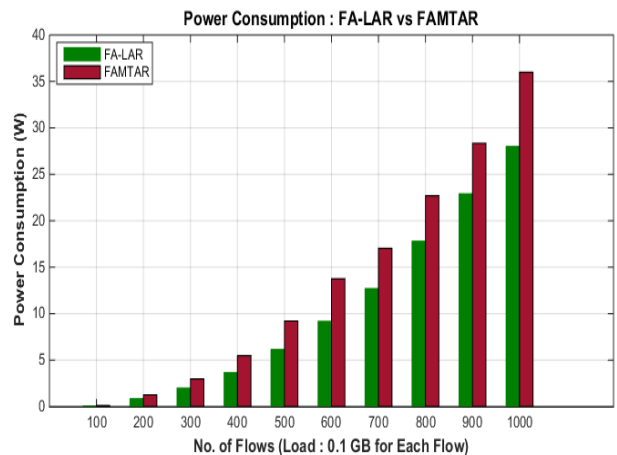


Fig. 6: Power Consumption Analysis of the Proposed FA-LAR.

The proposed Flow-Aware mechanism handles Energy Dissipation and Traffic Losses as well and hence the proposed FA-LAR achieves better Power Consumption and Load Deviation with Link Load against Traffic Load as well. These are shown in the Fig. 6 and Fig. 7.

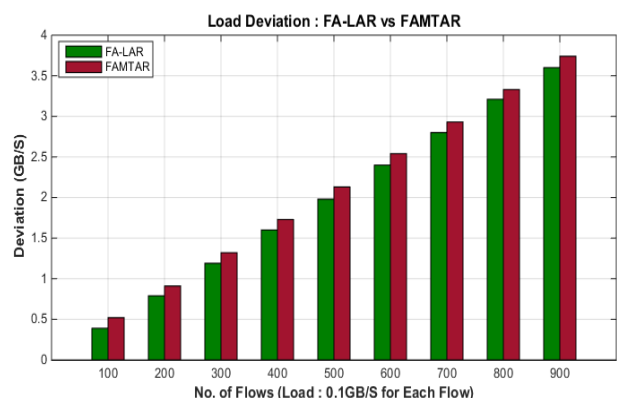


Fig. 7: Load Deviation Analysis of the Proposed FA-LAR.

6. Conclusion

This research work implemented Flow-Aware Multi-Topology Adaptive Routing (FAMTAR) in ns3 and studied thoroughly and revealed that this model unable to: i. detect and manage bulk flow, ii. Control Traffic Loss and iii. Maintain Deviation of Links Load against Traffic Load. This research work proposed an efficient Flow-Aware based Load Adaptive Routing (FA-LAR) to address the above mentioned issue. The proposed Model is implemented in ns3 and the simulation results are analysed thoroughly. From the experimental results, it is noticed that the proposed Model, FA-LAR is outperforming the existing FAMTAR in terms of Throughput, Queuing Delay, Power Consumption (Energy Dissipation), and Load Deviation.

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