

Modified ECMP Routing Using Adapted Cost Disjoint Multiple Paths ACDMP

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Abstract Computer network routing is performed based on routing protocol decisions. Open Shortest Path First OSPF is the most known routing protocol. It suffers from congestion problem since it generally uses single (least cost) path to deliver information. Some times OSPF delivers information using more than one path in the case of more than one path have the same cost value. This condition is rarely achieved in normal cases. In this work OSPF is developed to distribute information load across multiple paths and makes load distribution as general case for the routing protocol. The modification supposes no protocol replacement and uses the existing protocol facilities. This makes faster information delivery, load balancing, less congestion, and with little modification on the built in OSPF functions. Disjoint paths are calculated then the costs of the best set of them are adapted using appropriate ratio.

Index Terms— Computer Network Routing, ECMP, OSPF, Network Congestion, ACDMP, Multi-Path, Load Balance.

I. INTRODUCTION

Multipath routing is a form of routing in which network traffic can be split throughout several network paths to deliver data packets from source to destination using these available paths. It is recognized to be more efficient approach than well-known single path routing due to traffic splitting. Multipath routing provides load balancing, improves network bandwidth utilization, and mitigates network congestion [1].

In general, Multipath routing is an alternative approach to single path one that uses best path routing that splits the given traffic load among several “good” paths instead of routing all traffic along a single “best” path [2]. To use multipath routing, two issues need to be solved as critical problems that are finding multiple paths and the distributing manner of traffic along those paths [1].

One famous solution of multipath routing is Multiprotocol Label Switching (MPLS) [3][4]. It is a forwarding scheme introduced to support multipath routing. With MPLS, each packet has a special header containing fixed length labels [5]. Forwarding decisions are based on these labels.

MPLS needs a special Label Switching Router (LSR) to perform the multipath routing. An LSR uses the label as index to look up forwarding table [6]. MPLS fraught with many problems such as it needs special header that should be included in each packet, special routers, and it needs supporting signaling and reservation protocols.

Open Shortest Path First OSPF that is currently used in Internet has a property of equal cost multipath routing ECMP. ECMP is an approach already included in OSPF as an integrated unit that allows it to include multipath routing without need to any additional protocols or special configurations. If there are several shortest paths with equal cost, OSPF splits the load to be delivered between the source and destination and evenly distribute load among these available paths in ECMP approach. ECMP is very important in case of load balance and congestion control. However, ECMP is limited in real networks because the equal cost condition chance is rarely fulfilled due to connectivity limitations in the network [7] and Load sharing cannot be done across multiple paths having different cost. One way to make ECMP to be used in wider range is the tuning of link weights and affect shortest path

computation, in order to achieve traffic distribution [8]. Unfortunately, finding a good set of weights using weight setting problem WSP takes a long time to be computed using optimization problem and tuning weight may lead to instability.

In this paper ECMP is modified in a manner that allows it to be used in wide space and hence lead to more load distribution. This can be performed by adding equalization, adaptation, stage working after computing total paths connecting source-destination pair. As a result, unequal cost paths are used for load distribution in OSPF networks after little modification in the standard OSPF routing protocol.

II. OSPF ROUTING PROTOCOL

Open Shortest Path First OSPF is one of the more popular interior gateway routing protocols [9] that distributes its routing information inside autonomous system (AS) [10]. It is widely used and the dominant routing protocol in Internet [2]. OSPF routing operation requires Autonomous network splitting into multiple areas in which area connecting is done through a single area called the "backbone area". An area contains routers and host devices [10]. OSPF maintains a database called link state database that has information about the links, link cost and network connectivity. Link state information is exchanged through messages referred as Link State Advertisements between OSPF routers. Each router uses the link state database to generate the set of paths between it and every node (router) in the network. This can be done using Dijkstra algorithm [11]. Dijkstra algorithm determines the shortest paths between any two nodes in the network. The shortest path (also called least cost route) is the path that has less link cost combination. Link cost value or weight is assigned to each link by network administrator. After shortest path is determined for each node in the network, router constructs its own routing table. Routing table entry contains the destination node and the next hope router to follow to reach destination using the predetermined shortest path. In OSPF networks, each node transfers data to other nodes through a number of intermediate

nodes (routers) following the shortest path between edge nodes [2]. Source-destination pair transfers its data along that path between the source and destination.

III. EQUAL COST MULTIPATH ECMP

OSPF is a link-state protocol based on the shortest path first (SPF) algorithm. SPF algorithm calculates a single shortest path between source station to a destination station. Equal Cost Multipath technique is enabled to be used if several equal cost paths in IP routing are available [9]. This feature allows packet distribution on different outgoing links connects the source and the destination [2]. Using ECMP, a router can evenly distribute the current load over all available shortest paths that have equal lowest cost. This approach allows better load distribution and faster recovery in case of failure occurrence. Thus ECMP may improve network performance significantly and enhance efficiency [12]. The main advantage of ECMP coming from its integration in OSPF standard that makes it is already available in conventional OSPF router [5] and does not require any additional configuration [10]. ECMP is limited in use practically because in real networks the equal cost condition is rarely founded due to connectivity limitations and the need of special weight setting for network links.

IV. THE PROPOSED ACDMP

ECMP extension of shortest path protocols supports OSPF routing protocol with good facilities including load balancing that is important solution for congestion problem without the need of any complex additional algorithms. However in practical networks it needs special environment and complex calculations to satisfy the conditions of equal paths between source and destination. The proposed modification allows the ECMP to be available in conventional network as general case rather than rarely achieved condition. The paths through which data will be distributed need not originally to be equal cost paths. The paths are made equal using additional stage, the cost adaptation stage. Other condition is also achieved here that is the available adapted cost

multiple paths are chosen to be totally disjoint. These paths are called adapted cost disjoint multiple paths ACDMP. All ACDMP paths have the same cost value, after adapting original costs, and hence treated as ECMP by OSPF routing protocol. Thus, traffic load for a given source-destination pair is evenly distributed among ACDMP in the same manner in which OSPF distribute load among ECMP. The difference between ACDMP and ECMP is not in the manner in which load is distributed but in the interpretation and attributes of the equal cost paths. The proposed adapted cost disjoint multiple paths ACDMP includes two parts: the disjoint multi paths and the adaptation stage.

A. Disjoint Multi paths

The first step of the proposed adapted cost disjoint multiple paths approach is to find all available disjoint paths connecting the given source destination pair. Disjoint paths calculation is identical to shortest path calculation and use the same algorithm, the Dijkstra algorithm. The first calculated path between nodes i and j is the shortest path as it is done by traditional OSPF routing protocol.

$$Path(i,j)_1 = Dijkstra(i, j, A) \quad (1)$$

where A is the adjacency matrix describing network connectivity in the given network topology.

The Dijkstra algorithm is then repeated after excluding network links used in the first shortest path to calculate second shortest path. After that, Dijkstra algorithm is further repeated after excluding those network links used in the first or second shortest path. This process is repeated until no more paths are obtained.

$$Path(i,j)_n = Dijkstra(i, j, A \setminus \{\forall link \in \{Path(i,j)_1, Path(i,j)_2, \dots, Path(i,j)_{n-1}\}\}) \quad (2)$$

The set of all paths are named disjoint multi paths. Each path of these disjoint multiple paths together with its cost are fed to the adaptation stage.

B. The Adaptation stage

The adaptation stage receives all disjoint paths between any given source-destination each with its own cost and selects subset of these disjoint paths set to be used as adapted cost disjoint multi paths. The decision of path selection process is based on a path cost ratio PCR. The path adaptation stage selects the first shortest path and all other disjoint paths with path cost no more than PCR percent of the shortest path. The selected disjoint multiple paths costs are replaced with the first shortest path cost.

For each i - j pair of routers and for each available number of paths (K) connects them. It compares the cost values of each disjoint path with the cost of the least cost path obtained originally for OSPF. If the cost of a given disjoint path is no more than PCR percent of the least cost path (shortest path) then the disjoint path cost is logically set to the same value of the cost of the shortest path connecting the i - j routers. The number of the equalized disjoint paths that satisfies the condition is called equalized cost paths EP as:

$EP=1$

For $k=1$ to K

Begin

If $path\ cost(i,j)_k < PCR * Least\ cost\ path_cost$

Then $cost(i,j)_k = Least\ cost\ path_cost$

$EP=EP+1$

End for

End

If the number of the equalized disjoint less than the predefined number of equal cost paths ECP, the shortest path itself is used twice or more to complete this number of paths and hence used for forwarding more data.

Hence more than one path have the same path cost, after the adaptation stage. OSPF routing protocol will see more than one path with the same cost as if they are originally equal cost paths. OSPF will use the integrated ECMP

strategy to distribute network load among these paths.

V. NETWORK TOPOLOGY

The network topology that is used in this work is shown in Fig. 1. The proposed topology of test network can be considered as either complete autonomous network system (AS) with router 5 is set as boundary router or as a single area with a single border router that is router 5. This proposed topology may be interpreted as a campus or even a complete network of a given university. The proposed topology consists of a number of network identity or routers nodes connected by links edges. It consists of 16 links and 9 routers. These links can be treated as 32 unidirectional links.

Traffic demands for proposed network load is assigned to terminal node routers in four different load styles or scenarios in order to accommodate in account different working states on computer network run time conditions. Each traffic load demand scenario includes demand load with long time duration such as three hours in this work. During the simulated time period, network load demand is changed dynamically in a manner that may lead to several network congestion situations, in the proposed test topology when run under traditional OSPF routing protocol, and can reflect the non-stationary nature of network load changes. Load demands are shown in Table I.

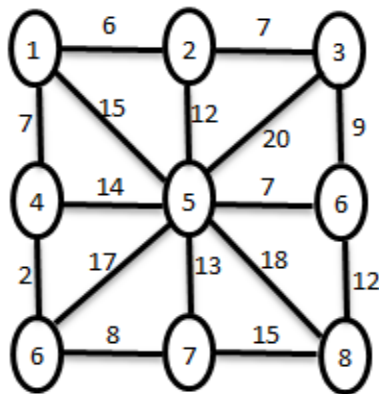


Fig. 1 Test network topology

TABLE I. THE PROPOSED LOAD SCENARIOS

| Load Style | Description |
|------------|---|
| 1 | Light load is assumed through several routers while other terminal routers are free of load. |
| 2 | All routers have moderate load that is changed in a manner that occurs several links congestion in separate time intervals. |
| 3 | All routers have network load assigned to them so as to providing more congested links in simultaneous manner. |
| 4 | Heavy load is applied to all routers. Load provides more links congestion simultaneously with significant packet loss and delay |

VI. RESULTS

The proposed algorithm, ACDMP, is applied on the test network topology shown in Fig.1. Network routing construction and performance measure results are obtained and compared with such results obtained from applying currently used traditional OSPF.

When network paths are determined by OSPF, routing table of the central router, R5, will contain routing information based on the shortest paths between each router and R5. Table II lists the shortest path for each router represented as a sequence of routers. All load demands between a given router, router i, and R5 will be delivered through this single shortest path connecting them.

TABLE II. OSPF PATHS

| Router | Path1 | cost |
|--------|-------|------|
| 1 | 1-5 | 15 |
| 2 | 2-5 | 12 |
| 3 | 3-6-5 | 16 |
| 4 | 4-5 | 14 |
| 6 | 6-5 | 7 |
| 7 | 7-4-5 | 16 |
| 8 | 8-5 | 13 |
| 9 | 9-5 | 18 |

In the proposed ACDMP, path calculation will be performed in two stages. In the first stage, all the disjoint paths are calculated for each router in the network as shown in Table III. These paths together with cost values are fed to the adaptation stage.

TABLE III. THE DISJOINT PATHS

| Router | Path1 | | Path2 | | Path3 | |
|--------|-------|----|---------|----|---------|----|
| 1 | 1-5 | 15 | 1-2-5 | 18 | 1-4-5 | 21 |
| 2 | 2-5 | 12 | 2-1-5 | 21 | 2-3-6-5 | 23 |
| 3 | 3-6-5 | 16 | 3-2-5 | 19 | 3-5 | 20 |
| 4 | 4-5 | 14 | 4-7-5 | 19 | 4-1-5 | 22 |
| 6 | 6-5 | 7 | 6-3-2-5 | 28 | 6-9-5 | 30 |
| 7 | 7-4-5 | 16 | 7-5 | 17 | 7-8-5 | 21 |
| 8 | 8-5 | 13 | 8-7-4-5 | 24 | 8-9-5 | 33 |
| 9 | 9-5 | 18 | 9-6-5 | 19 | 9-8-5 | 28 |

Adaptation stage uses these disjoint paths, PCR, and the predefined number of equal cost paths ECP links to be generated to generate the adapted equalized disjoint multi paths. As a result , the final set of equalized multi paths with of the adaptation stage applied on paths of Table III with ECP=3 is shown in Table IV.

TABLE IV. THE ADAPTED ECMP PATHS

| Router | Path1 | | Path2 | | Path3 | |
|--------|-------|----|---------|----|-------|----|
| 1 | 1-5 | 15 | 1-2-5 | 15 | 1-4-5 | 15 |
| 2 | 2-5 | 12 | 2-1-5 | 12 | 2-5 | 12 |
| 3 | 3-6-5 | 16 | 3-2-5 | 16 | 3-5 | 16 |
| 4 | 4-5 | 14 | 4-7-5 | 14 | 4-1-5 | 14 |
| 6 | 6-5 | 7 | 6-5 | 7 | 6-5 | 7 |
| 7 | 7-4-5 | 16 | 7-5 | 16 | 7-8-5 | 16 |
| 8 | 8-5 | 13 | 8-7-4-5 | 13 | 8-9-5 | 13 |
| 9 | 9-5 | 18 | 9-6-5 | 18 | 9-8-5 | 18 |

Thus, data packets between router 5 and router 1 (for example) are routed on three different disjoint paths. These paths are treated by OSPF exactly as they are originally of equal cost. And are served by the integrated ECMP.

Network performance is then measured for the proposed routing on network topology and load scenarios shown in Fig. 1 and Table I respectively. The measured network performance factors include link load utilization, Queuing Delay QD, and Packet Loss Ratio PLR. In

additional to these factors, the number of links used from the network to carry data (No. Links) is find to be 20 for the proposed ACDMP while it is just 8 in traditional OSPF. This indicates that the proposed approach make more link usage (more than twice that used in OSPF).

These factors give good indication about the congestion state within the network. These factors are also measured for the same network but with the currently running OSPF protocol for comparison purpose. Simulation results are shown in Table V.

TABLE V. ACDMP VS. TRADITIONAL OSPF PERFORMANCE

| scenario | Metric | ACDMP | OSPF |
|----------|-----------|--------|--------|
| 1 | Max Load | 98.347 | 100 |
| | Av Load | 61.144 | 76.498 |
| | QD sec. | 1.221 | 13.308 |
| | PLR % | 0 | 0.1869 |
| | No. Links | 20 | 8 |
| 2 | Max Load | 98.666 | 100 |
| | Av Load | 66.748 | 78.777 |
| | QD sec. | 1.861 | 14.117 |
| | PLR % | 0 | 0.193 |
| | No. Links | 20 | 8 |
| 3 | Max Load | 98.659 | 100 |
| | Av Load | 62.989 | 77.394 |
| | QD sec. | 1.983 | 9.463 |
| | PLR % | 0.0008 | 0.1164 |
| | No. Links | 20 | 8 |
| 4 | Max Load | 100 | 100 |
| | Av Load | 68.582 | 82.131 |
| | QD sec. | 3.677 | 15.937 |
| | PLR % | 0.0027 | 0.247 |
| | No. Links | 20 | 8 |

From Table V, Max. Load utilization is always 100% for traditional OSPF while it is a bit less than that for the proposed ACDMP except with scenario 4. A 100% Max. Load utilization means link load full range and indicates packet loss. Average Load utilization (Av. Load) values for ACDMP less than that for traditional OSPF in all load scenarios since ACDMP has better load distribution. That enlightens load over the used network links. Queuing delay QD is very low as compared to OSPF QD of the same conditions.

Packet loss ratio PLR is very low when compared to that of OSPF.

VII. CONCLUSIONS

ACDMP algorithm proposed good modification for OSPF routing protocol that is currently running in Internet. The proposed algorithm uses all benefits and facilities of traditional protocol together with ECMP after generalizing it and making it more efficient. It is also making equal cost link load distribution a general state rather than rarely achieved condition. The other gain from the proposed algorithm is that load distribution for any source destination pair is done through disjoint paths so that no link is shared among the multi paths that ensure load utilization with more load capacity. It is obvious from the obtained results that the proposed ACDMP algorithm is better than traditional OSPF since it has less queuing delay and less PLR and better link utilization and load distribution.

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