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Offline Constraint-based Routing in OSPF Networks: A Server based Study

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Summary

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ABSTRACT

Many of the network applications today are demanding QoS guaranteed paths which the best effort routing protocols e.g. OSPF cannot calculate, because these protocols are topology driven, do not address many of the constraints by these applications and only calculate shortest paths. In this thesis offline constraint based routing is studied for Open Shortest Path First (OSPFv2) protocol single area network and an offline server is proposed for QoS guaranteed routing. The server builds traffic engineering (TE) database and calculates QoS guaranteed paths on behalf of all the routers in that area. The client routers only do best effort routing for normal data flows with no requirement for QoS guaranteed paths. The client routers use NETCONF protocol to download QoS routes from the offline server (OS). The offline server besides calculating QoS paths also reduces congestion and helps in efficiently utilizing the network resources, for example bandwidth.

Keywords

Constraint-based routing, offline server, QoS routing, traffic engineering, OSPFv2, Traffic engineering database.

1. Introduction

Best effort routing cannot handle traffic flows which require QoS guaranteed paths due to constraints posed by these flows. Also this traditional best effort routing is not suitable for traffic engineering. Best effort routing protocols only select shortest paths, are topology driven and do not consider other constraints in the path calculations. The current use of topology-driven routing protocols with shortest path calculations often leads to serious imbalance of traffic volume when least cost paths converge over the same set of links and router interfaces, leading to traffic congestion with unacceptable packet delays or packet loss. Such service-affecting inefficiencies can occur dynamically, and despite the presence of feasible paths over less utilized links undiscovered by the shortest path algorithms employed by the network routers [1].

To solve some of the best effort routing limitations, a number of algorithms and methodologies have been proposed recently, mostly based on the concept of routing with resource reservation using constraint-based routing or QoS based routing algorithms.

[2] Also proposes a combination of Multi-Protocol Label Switching (MPLS) [3], CBR and enhance IGPs to address the above problems.

For providing QoS guaranteed paths to network applications routing protocols need to consider many constraints while routing network data. This has lead to a new area in computer networks which is called constraint-based routing (CBR) where besides traditional best effort routing different constraints are met to forward data packets. Constraint-based routing solves many problems faced by the best effort routing currently routing protocols perform.

Bellow is few definitions of CBR from the literature followed by the OSPFv2 support for Offline CBR.

In [4] CBR is defined as Constraint-based routing and is used to compute paths that are subject to multiple constraints. CBR evolves from QoS routing. Given the QoS request of a flow or an aggregation of flows, QoS routing returns the route that is most likely to be able to meet the QoS requirements. Constraint-based routing extends QoS routing by considering other constraints of the network such as policy. Both QoS based routing and policy based routing can be considered as special cases of Constraint-based routing [5].

Constraint-based routing is the term referring to path assignment to flows in the domain for the purpose of TE. The TE objective generically describes as load balancing or efficient utilization of network resources while meeting the resource requirements of the flows [6]. Constraint-based routing algorithms select a routing path satisfying constraints that are either administrative-oriented (policy routing) or service-oriented (QoS routing). The routes, in addition to satisfying constraints, are selected to reduce costs, balance network load, or increase security [7].

Currently there are two types of routing protocols implementations: distance–vector routing and link state routing protocols. In distance-vector routing, the routing algorithm follows a distributed model and do online calculations e.g. RIP [8]. In link state routing, the routing algorithm is centralized for example OSPFv2 [9] and IS-IS [10]. Even in these cases, each router executes its own instance of the routing algorithm and is capable of determining its own routes and is not used for centralized execution of the routing algorithm and path calculations [11].

There are two types of Constraint-based routing:

- Online constraint-based routing, in which each router locally calculates QoS routes.
- Offline constraint-based routing where a separate device, for example a route server is used to calculate QoS routes on behalf of all other routers in the network.

Offline CBR is performed on a network server which is only dedicated to collect network state information and calculate QoS paths for routers and switches participating in the network topology. This information can be the current available resources in the network, like available bandwidth etc.

This paper presents offline constraint-based routing (CBR) solution to the best effort routing problems exclusively for the OSPFv2 interior routing protocol and an offline server is used which calculates QoS guaranteed paths offline for the network flows. This server is an improvement to the previous server based QoS routing utilizing constraint-based routing in OSPFv2 protocol. The Offline Server only calculates QoS guaranteed routes leaving the rest of the routers in the area to calculate best effort routes locally. Performing most of the tasks of QoS routing in a server, allows the other routers to remain simple and to a large extent unaware of the introduction of QoS capabilities [11]. The client routers download the QoS paths from the server using the NETCONF [12] protocol. The NETCONF protocol is recently standardized for automatically configuring network devices like routers and switches involving client server architecture.

This offline CBR server based routing approach is limited only to single area OSPFv2 protocol using Broadcast Multi-access and Non Broadcast Multi-access networks. Frequent requests for QoS routes from multiple client routers introduce processing overhead on the server. Path caching technique has been studied in [11] for reducing such processing load on server.

This implementation is somewhat similar to Bandwidth Broker (BB) [13] or TEAM (Traffic Engineering Automated Manager for DiffServ-Based MPLS Networks) in [14] or Routing and Traffic Engineering Server (RATES) developed for MPLS [15].

Next comes related work section where three papers on server based routing are discussed followed by Architecture of the offline server section which has three sub-sections. Following concluding remarks is future work. Finally acknowledgements finish the paper.

2. Related Work

In literature a lot of research has been conducted on constraint-based routing with Multiprotocol Label Switching (MPLS) protocol for traffic engineering in internet while little attention has been given to CBR in interior routing protocols and specially offline CBR for Traffic engineering and QoS routing in OSPF protocol.

There are three research papers which have studied server based scheme for routing in interior protocols. These papers are discussed bellow.

In [11] the authors have proposed server based QoS path calculation for interior link state routing protocols. Only server keeps all the topology information and calculates the QoS routes. Authors have discussed some advantages of server based routing over distributed routing and have shown that server based routing is possible using the current networking devices. But there is no specific discussion on server based routing for OSPF routing protocol.

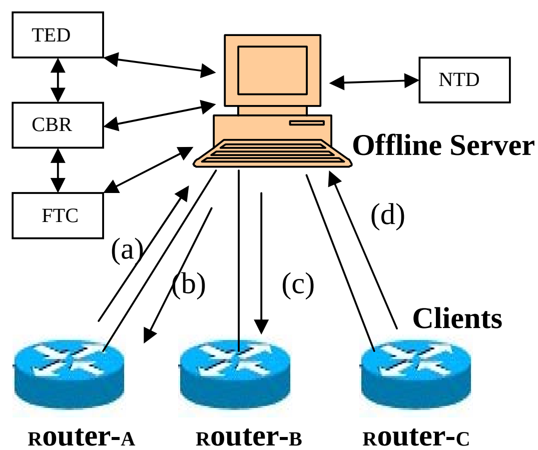
Another paper [16] also proposes server based QoS routing for interior link state routing protocols but this approach is deterministic which means that all the link state information is explicitly maintained by the route server in advance and route caching is used to reduce load on route server.

Also in [15] Server based routing is proposed for Traffic engineering in MPLS networks using OSPF topology database. This server uses peering mechanism of OSPF to obtain topology information and binary link and node states (up/down). In addition, to obtain QoS related link and nodal attributes, the server uses graphical user interface (GUI) the network administrator can use to provide necessary parameters and constraints. This server based approach requires manual work and also is not utilizing the new traffic engineering extensions to OSPFv2.

The offline server solution to best effort routing problems in this paper is an improved version to the server based QoS routing [11] and [16]. The offline server is using different link state information collected by the new traffic engineering extensions to OSPFv2 in [17]. Also the offline server uses NETCONF protocol to provide access to QoS routes required by the client routers in the area which is an attempt towards auto configuration of network devices.

3. Architecture of the Offline CBR Server

Figure 1 shows the basic components of the proposed offline server based routing architecture and the protocol primitives that are used for communications between the client routers and server. The offline server maintains five different modules: Traffic engineering database (TED), Normal topology database (NTD), Forwarding table cache (FTC), Constraint-based routing (CBR), if a new request arrives at a client router, the client sends out a Path Query (PQ) message to the offline server to ask for a new path for the requesting QoS flow. Receiving the PQ message, the server computes a new path using the network state information in TED or selects an appropriate QoS path from the FTC for the request. The server then updates the TED to reflect the Resource assignment to the links that belong to the assigned path. The route server replies to the client with a Path Reply (PR) message, which includes the explicit QoS path information for the request. If there is no path available for the request, the server sends out Path Block (PB) message to the client. When a QoS flow finishes, the client that has requested the QoS path for the QoS flow sends out a Path Return (PT) message to the server. A PT message indicates the returned path so that the route server may update the link QoS state information in the NTDB for those links constituting the returned path. For reliable communications between the client routers and offline server, NETCONF protocol is used.



(a): Path Query (PQ)
(b): Path Reply (PR)
(c): Path Block (PB)
(d): Path Return (PT)

Figure. 1

The offline CBR server consists of three functional parts namely offline TE database in the server, path computations and QoS routing algorithms, and implementation issues.

3.1 Offline Server's TE Database

Constraint-based routing needs extended link attributed for intelligent decision regarding QoS guaranteed paths. TE extensions to OSPFv2 in [17] are used to collect link attribute required by constraint-based routing and build traffic engineering database. The extensions to OSPFv2 define new traffic engineering LSA. OSPF routers use link state advertisements to exchange routing and topology information. The new traffic engineering LSA can provide with many attributes of the link in the network for CBR for example maximum reserve able bandwidth, unreserved bandwidth, traffic engineering metric etc (see [11] for more details on traffic engineering LSA).

This section discusses the Traffic engineering database (TED) of the offline server. The offline server using Hello protocol [18] becomes designated router for the broadcast multi-access networks and non-broadcast multi-access networks. The remaining routers make adjacency with the offline server and act as the client for the configurations. The Hello protocol is primarily responsible for dynamically establishing and maintaining neighbor adjacencies. The client routers exchange the link state information with the offline server. The traffic engineering LSA is generated by all the client routers. The Traffic engineering LSA is flooded using opaque LSA type10 which has an area scope. The existing network LSA is sufficient for describing Multi-access links.

There are two databases in the server. One is normal topology database and the other is TE database. The server is assumed to be powerful and has sufficient memory to keep and process two databases. The server maintain normal topology database to keep updated client routers about change in the network and minimize the routing between the routers. TED database is used by the server for calculating the QoS guaranteed routes and traffic engineering purposes.

Operational: When the OSPF routing starts in the area, the server is elected as the designated router for that area and the routers become neighbors to the server. All the remaining functionalities for database description etc are the same as the standard OSPF v2, besides other LSAs the router also generates a traffic engineering LSA that is flooded and received by the server. The server does not generate traffic engineering LSA it only accepts traffic engineering LSA and updates TE database. Server generates LSAs when it receives normal topology change from a client router and to propagate that information to the remaining routers in the area.

Routers shall originate traffic engineering LSAs whenever the LSA contents change and whenever otherwise required by OSPF (an LSA refresh, for example). If there is a minor change then it is not necessary to generate traffic engineering LSA. A bandwidth threshold can be used to generate traffic engineering LSA. To reduce the frequency of link state advertisements, one possible way is to distribute them only when there is topology or significant bandwidth changes (e.g., more than 50 percent or more than 10Mb/s) [19].

[1] Presents several key results on the performance of the recently proposed OSPF-TE, with particular emphasis on OSPF-TE protocol traffic overhead and the impact of new link state advertisement triggering mechanisms on traffic-engineered routing accuracy. Stability issues in OSPF have been studied in [20].

The usage of the traffic engineering database is not so much frequent because it is used in case there is request for QoS route from the client routers. Upon receipt of traffic engineering LSA or network LSA the server should not run algorithm for calculations because this information is used when there is a query regarding QoS routes.

3.2 Path computations and QoS routing algorithms

When there is a request from a client router for a QoS route, the server first checks the FTC for the route. If there is no route in the FTC then it runs a CBR algorithm on the TED and returns a QoS route to the client router.

Constraint-based routing path computation algorithms' complexity depends on metrics that is chosen for the routes. In constraint-based routing, common path metrics can be bandwidth, monetary cost, hop count, reliability, delay and jitter. Routing algorithms select routes that optimize one or more of the above metrics.

Generally metrics are divided in two three classes. Let $d(i, j)$ be a metric for link (i, j). For any path $P = (i, j, k... 1, m)$, metric d is [21]:

Additive if $d(P) = d(i, j) + d(j, k) + ... + d(1, m)$

Multiplicative if

$d(P) = d(i, j) * d(i, k) * ... * d(1, m)$

Concave if

$d(P) = \min\{d(i, j), d(j, k), ..., d(1, m)\}$

According to this definition, metrics *delay, jitter, cost,* and *hop count* are additive, *reliability* (1 - loss rate) is multiplicative, and *bandwidth* is concave.

A well known theorem in constraint-based routing is that the algorithms that use two or more of delay, jitter, hop count, and loss probability as metrics and optimize them simultaneously are NP-complete. The computationally feasible combinations are bandwidth and one of those metrics [22].

There are many algorithms in the literature which can be run on the information in the traffic engineering database of the offline server. Four of these are discussed here:

1) SPF-TE (Shortest Path First with Traffic Engineering) [23], this algorithm selects feasible paths with least number of hops. **2)** WSPF (Widest Shortest Path First) [24] uses hop count and available bandwidth to select a path. If more than one path is available then the one with maximum residual bandwidth is selected. **3)** DORA (Dynamic Online Routing algorithm) [25] is an online routing path algorithm in MPLS networks and is used to avoid routing over links that have high potential to be part of other path and has low residual available bandwidth. **4)** MIRA (Minimum interference routing algorithm) [26] selects least interference paths with future request. Performance evaluation study of the first three has been performed in [27].

MIRA algorithm is being recommended to run on the TE database of the offline server for calculating QoS guaranteed paths. It has been used because it calculates QoS guaranteed routes and avoids interference of the paths in the future requests.

3.3 Implementation issues

The main issue when implementing a server based routing architecture is the communication between client routers and the offline server. In particular, message exchanges are needed for the route request /reply operation, sending link state updates to the server. Some of these message exchanges, in particular the route request/reply, need to be reliable. As discussed above for the exchange of link state information OSPF LSAs are used between the offline server and the client routers. NETCONF protocol is being used for downloading QoS routes from offline server to the client router. The NETCONF protocol uses a remote procedure call (RPC) paradigm. A client router encodes an RPC in XML [28] and sends it to a server using a secure, connection-oriented session. The server responds with a reply encoded in XML. The NETCONF protocol is a building block in a system of automated configuration.

4. Concluding remarks

Offline constraint-based routing concept is used to solve best effort routing problems in OSPFv2 networks. Using offline CBR support in OSPFv2, an offline server is calculating QoS guaranteed routes. The offline server functions as designated router and keeps adjacency with the other routers in that area. The routers in area generate traffic engineering LSA and flood it using opaque LSA type10. The offline server receives traffic engineering LSA and builds a TE database. MIRA algorithm calculates QoS guaranteed paths which the client routers download using the NETCONF protocol. This offline server based routing avoids overlapping of the routes and underutilization of the links.

5. Future Work

The offline server in the paper is a theoretical study for offline constraint-based routing in OSPFv2 networks. This improvement of server based QoS routing is limited to OSPF single area networks and its study and implementation for OSPF domain level networks is left ad future work. Also this study needs simulation before actual implementation is performed. Different QoS routing algorithms other than MIRA can be tested on TE database to calculate QoS guaranteed routes. This offline server based routing can be tested for bandwidth specific applications like multimedia services and be further improved. Further integration of the NETCONF protocol can make the network administrator’s job easy and better auto configuration of network devices.

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