Routing optimization in the transmission network

Mary Luz Mouronte, María Luisa Vargas, Paloma Martínez
Optical Network Provisioning
Ericsson
Madrid, Spain
mary.luz.mouronte.lopez@ericsson.com.

Abstract— **This paper describes a method to optimize the route lookup in a multivendor data transmission network built on Synchronous Digital Hierarchy (SDH) and Wavelength Division Multiplexing (WDM) technologies. The optimization is carried out in terms of time reduction, thereby having a wide field of application in network operation: restoring service after a failure, traffic redistribution scenarios, etc.**

The algorithm encompasses different aspects such as: number of routes to lookup, network structure, technological characteristics of routes, and situation of elements, all of them related to technical objectives. It also aims at integrating other features embodying other objectives apart from the aforementioned technical ones.

Keywords-component; route lookup optimization; SDH, WDM; transmission network features; transmission network elements; boundary conditions.

I. INTRODUCTION

The method to select a suitable path into a network for sending traffic is called routing. This process is carried out in different networks, particularly in data networks (data packet routing) and telephone networks (phone calls routed through numbering plans).

In **data networks**, the routing information is included into the final address codification. Routing tables are used at each node, and they contain adjacent node addresses, so it is not necessary to know the whole network topology.

Small networks can use manually configured routing tables, but when networks increase their size, manual management is unfeasible. This problem is intended to be resolved through automatic routing table creation. The process is based on the information included in the routing protocols, which allow the network to work in an autonomous way.

There are different kinds of algorithms to automatically populate the routing tables:

- Distance vector algorithms, based on the Bellman-Ford method [1]: each node assigns a cost to the distance to the known destine, and transmits it to the adjacent nodes. Each receptor builds its tables based on the received and stored information. If there is a node failure, the information is rebuilt in each one of the surviving nodes.
- Link state algorithm: each node shares its link information so all the nodes build a network map. This map is modified according to the link state. The route is obtained by means of basic short path algorithms, which assign cost to each link (Dijkstra algorithm, for example).
- Path vector protocol: a special class of distance vector algorithms, useful in very big networks.

All these algorithms (special mention to [2], [3], [4], and [5]) require features which make possible to establish a hierarchy among routes, such as bandwidth, delay, hop number and so on.

In **telephone networks**, routing tables are previously calculated in a centralized way. The main parameters for their elaboration are the network topology; the numbering plan and the traffic data analysis (see [6]).

Due to geographical and hierarchical structures, which are the base of the numbering plans, almost all telephone calls are routed using only the first numbers (prefix). The tables are designed specifically for each switchboard, so the maximum number analysis is defined for the geographical zone managed by the switchboard.

There is no dynamic route selection when there is a failure within the network. All the alternative routes are selected at the same time than the main ones.

As we can see in all the previous cases, the techniques used in each network are based on their specific characteristics, which are not useful in the **data transmission network**:

- In data networks, the routing table design, regardless of the selected method, is based on parameters that make possible to assign a cost to every links. In transmission networks, there is no measurable parameter that can be used to prioritize the paths. The only specific requirement at this point is to avoid loops in the final route when the algorithm selects a path in a node among different possibilities. In other words, an already visited node at the end of a possible path discards that path.
- In telephone networks, the routing table design is static, based on the network structure and the information included in the telephone numbers, with no dynamic selection. In transmission networks, there are static paths too, but if the network fails, the new path is selected dynamically. In this situation, there is no more static information than the network topology, so there is no hierarchy that can be used to select a

Copyright (c) IARIA, 2011.

path. All the routes with available bandwidth have the same priority; there are no criteria to discard.

There are some recent studies aimed at route lookup in transmission networks, as it is a key point in the deployment of the future high capacity networks, all-based in optical links. There are some novel approaches to this problem, as it is developed in [9], applied to power networks but useful for optical networks too. There are some works too for calculating routes after deployment, in a general way as it is mentioned in [10] or oriented to a specific kind of traffic, such as the one analyzed in [11].

However, almost all of these works are focused on static calculation or pre-calculated routes, while our work is focused on real-time lookup without pre-evaluated routes. They are oriented to isolated networks (in terms of technology), not mixed ones, each island with different restrictions and conditions.

After the evaluation of all these points, the first step in the work will be the selection of the characteristics of the data transmission network that will facilitate the optimum route selection in a dynamic way according to network status. Subsequently, the work will describe the modifications in traditional algorithms to use all the selected features in the lookup.

II. DATA TRANSMISISION NETWORK CHARACTERISTICS

The procurement of a customer service between two points in the transmission network requires a route selection and setting between them, usually involving various nodes (equipments) aside from the access equipments. In normal service procurement, the route selection and setting is carried out at the circuit-provisioning step.

However, an additional situation requires a route selection. If there is a network failure, it will be necessary to turn aside the traffic in order to ensure the service. In that case, there is no previous selected route, so a new one must be selected and set at that moment. What is more, main concerns must be: the speed, a minimized traffic lost, and network status, to avoid failed equipments or connections.

The algorithms for data networks outlined before are very generic, and no efficient in particular ones, as it is showed by the modifications in the telephone network routing.

This work describes the adjustments of the previous algorithms to the data network characteristics, so a best efficiency can be achieved. The bandwidth required for a route within the data transmission network is translated into a signal type, and the viable route is defined through the relationship between different paths according to this signal type. The work takes into account different features, which at the end define the network in terms of signal types:

- **Hierarchy**: The network is hierarchically organized according to an increasing bandwidth. Paths with a specific signal type (i.e., a required bandwidth) are joined into another one with a higher one.
- **Safeguard**: At some hierarchic levels, there are path groups defining structures for traffic safeguard. These path groups must be taken into account for the route definition (e.g., path rings).
- **Technology**: Data transmission networks include a wide range of technologies. Within them, there are easier ways to switch routes (e.g., if the lambda switching can be remotely done in an optical network, this routing will be faster and more efficient than if it is necessary to make the switch in the equipment), directly affecting the delay in traffic restoration.
- **Network deployment**: The network capacity changes dynamically, so the information about the network topology must be properly updated for an efficient route lookup. The network can mainly change in three different ways: deployment (i.e. adding new equipments or paths resulting in an increased capacity); network variations due to failures, (decreasing capacity) or path redesign (changing relationships) and finally service provisioning, which decreases the network capacity.

III. ALGORITHM

This section describes the information included in the algorithm in order to use the specific selected features of the data transmission network to obtain optimized results. The algorithm is applicable to a multivendor transmission network.

The features outlined in the previous section are thoroughly explained below:

- Location (buildings): sites where the network equipment is placed.
- Transmission equipments within each location.
- Ports/points in each equipment: the equipment usually consists of a variable number of cards (depending of the equipment configuration) and each card includes a number of ports (depending on the card configuration). All of these are physical elements, but there is a logical element that must be taken into account, the termination point [7]. A physical port can be logically divided in different points, related to a specific signal type. A path can finish in a port or a point depending on its signal type, so the algorithm must differentiate and consider both of them.
- Links (paths) connecting equipments: The information handled by the algorithm is their free capability in terms of the number of paths and signal type of each one. This free capability can be modified according to the rules defined by the final points in the equipments, because there are specific configurations related to the equipment type and the network definition itself [7].
- Protection rings in the network: In a data transmission network, there are protection structures that ensure the traffic in some specific points, usually in big capability links. In these structures, there are usually two branches: one of them works in a normal way, and the

other is free (safeguard) until a failure turns up. At that moment, an automatic switch is performed and the traffic begins to flow through the free branch, keeping the service on. These structures are called “rings” and, in this work, they are described in terms of the equipments and links belonging to them.

All the necessary information in the algorithm must be updated dynamically, according to the variations carried out in the network topology mentioned before. These variations are translated on the assembly and disassembly of locations, equipments, ports, links and rings; configuration changes that modify the path that can be included into a link; and service procurement modifications (they entail link use, so the link capability is modified).

All the above information is related to the network structure. Nevertheless, there is additional information, regarding to the route itself which must be handled by the algorithm, so the lookup is optimized. The additional information is translated into the input parameters that the algorithm must receive, so it can obtain a route with the desired conditions:

- The **signal type** and **number** of routes the algorithm must lookup.
- The **termination points** or **ports** that are the ends of the desired route. As it is mentioned above, the route must use one or the other in both ends depending on the signal type.
- Required **route features**: These features can be expressed in terms of capability (a full link or only the needed bandwidth); possibility of network operations (links already have the desired capability or it can be achieved through configuration modifications); end situation (they must be in the same equipments or it is enough if they are in the same locations) and maximum number of links. The end situation must be taken into account because in certain conditions and technologies, it is not possible to reach the equipments and some hardware modifications are required. The maximum number of links is needed because sometimes the network is heavily messed [8] and the number of possibilities is dramatically increased, so this condition is a termination one.
- **Boundary conditions** as a route lookup limitation. These conditions include elements which must or must not be used (equipments or links) and rings where the route must be included. The first condition allows to avoid failed equipments or links, as well as to use other ones according to service requirements. The last one is necessary because, in some cases, the initial protection schemes must be kept.
- **Resource special features**. There are certain network conditions that can be useful to restrict the lookup, so it will be optimized. Usually they are related to the network status: to use failed resources if there is not other available route; to use temporary resources deployed only for a single scenario or another similar one. However, there is a special case related to network nature: to use only a specific kind of network (SDH or WDM, for example). This is necessary because, in some cases, there is no chance to send staff to manually switch routes, and the obtained route must allow automatic and remote operation.

The way the adapted algorithm works to find a route is outlined below.

The first step is to select the end equipment and the required resources according to all the input data. The next task is the lookup itself. There are three mutually exclusive lookups, depending on input data:

- Lookup into a ring.
- Lookup among locations.
- Lookup among equipments.

The first kind of lookup is the **lookup into a ring**. In this case, the first step is to get the equipments that constitute the ring. Next, the algorithm tries to locate a route defined only through links that belong to the ring (between those equipments).

For this lookup to get a valid route, it is necessary that the end equipments are included in the ring too. Although this condition could make think that it is not a very useful lookup, it can be valid if we are trying to restore the service in a specific point, and we define the set of links into the ring as the route that needs to be modified.

The algorithm can be formalized according to the next pseudocode:

```
GET EQUIPMENTS IN THE RING
IF (EqOri AND EqDes) IN THE RING
   SET EqIni = EqOri
   SET EqAnt = EqOri
   SET Route = ()
   LOOKUP:
       GET LINK RING (EqIni, Link1,
       EqDes1, Link2, EqDes2)
       IF (EqDes1 = EqDes) THEN
         ADD (Link1, Route)
         EXIT (OK)
       ELSE IF (EqDes2 = EqDes) THEN
         ADD (Link2, Route)
         EXIT (OK)
       ELSE IF UltEqu (EqDes1, EqDes2)
       THEN
         EXIT (NO_ROUTE)
       ELSE
         AsignEqu (EqAnt, EqIni, EqDes1,
         EqDes)
         GOTO LOOKUP
       END IF
```

The second type is the **lookup among locations**. This lookup is used, as mentioned before, when there is no certainty of obtaining a valid route totally defined through a sequence of links and equipments, but we think that there is a sequence of locations and links, so in this case the network modifications are minor ones.

The lookup begins at the initial location. From that point, links are selected and the end location of each one is explored in the same way. When the lookup arrives to a location where there is no available link or the route length reaches the maximum number of links and it is not the end location, it goes back until the last one where there are other available links and tries to go to a different location.

In this case, the first and last locations are obtained through the end equipments, but the rest of the locations are obtained through the name of the links, not the equipments where the links end. The link selection takes into account the actual capability or the possibilities, which can be achieved through some network configurations, according to the input parameters. It also takes into account the special resource features: in a normal way, only permanent and working resources are selected, and there is no network restriction. These conditions change if there is any special feature, so the selection is widened (failed and temporary resources) or restricted (only a special network).

The algorithm can be formalized according to the next pseudocode:

```
GET_Loc_Equ (EqOri, LocOri)
GET_Loc_Equ (EqDes, LocDes)
SET Route = ()

LOOKUP_LOC (LocOri, LocDes, Route, Res) ⇒
SET LocIni = LocOri
LOOKUP:
   SET Res = NOK
   FOR Link IN GET_LINK_AVAI (LocIni,
   ContCond, EspFeat)
       GET_Loc_Link (Link, LocIni, LocEnd)
       IF (LocEnd = LocDes) THEN
         ADD (Link, Route)
         SET Res = OK
         EXIT (OK)
       ELSE IF (Long (Route) = NumMax – 1)
       THEN
         Next (Link)
       ELSE
         LOOKUP_LOC (LocIni, LocDes, Route,
         Res)
         IF (Res = OK) THEN
              EXIT (OK)
         ELSE
              NEXT (Link)
         END
       END
   END
   EXIT (Res)
```

The last kind of lookup is the most useful of them, the **lookup among equipments**. In this case, the route ends are the equipments themselves, not the locations, and the links must connect directly these equipments.

The lookup begins at the initial equipment. From that point, links are selected and the end equipment of each one is explored in the same way. When the lookup arrives to an equipment where there is no available link or the route length reaches the maximum number of links and it is not the end equipment, it goes back until the last one with available links and tries to go to a different one. The link selection has the same considerations described in the previous point.

The algorithm can be formalized according to the next pseudocode:

```
SET Route = ()

LOOKUP_EQU (EquOri, EquDes, Route, Res) ⇒
SET EquIni = EquOri
LOOKUP:
   SET Res = NOK
   FOR Link IN GET_LINK_AVAI (EquIni,
   ContCond, EspFeat)
       GET_Equ_Link (Link, EquIni, EquEnd)
       IF (EquEnd = EquDes) THEN
         ADD (Link, Route)
         SET Res = OK
         EXIT (OK)
       ELSE IF (Long (Route) = NumMax – 1)
       THEN
         Next (Link)
       ELSE
         LOOKUP_LOC (EquIni, EquDes, Route,
         Res)
         IF (Res = OK) THEN
              EXIT (OK)
         ELSE
              NEXT (Link)
         END
       END
   END
   EXIT (Res)
```

The last step, after any type of lookup obtains results, is the boundary check, so the routes that do not fill the boundaries are discarded. This check does not include the condition related to ring use because it is translated into a type of lookup.

The algorithm receives the number of routes that must select, but time is an important matter that has to be considered, because the lookup is useful only if it obtains routes in a reasonable period. Therefore, there is a general timer, and when it ends the algorithms gives as an output all the routes selected until that moment, although the number is smaller than the required one.

Copyright (c) IARIA, 2011. ISBN: 978-1-61208-133-5

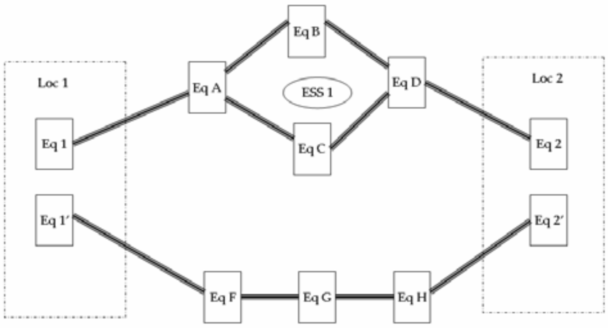

Figure 1. Topologic network view for a practical lookup

As the last step, we are going to explain the algorithm work with an example. In Fig. 1, we have a simplified network topology, where we can describe the expected behavior in each one of the lookups explained before.

In this topology, we have all the basic elements for the algorithm:

- Locations (Loc) and equipments (Eq), used for the route lookup.
- Rings (ESS), which define the protection schemes into the network.
- Links between the equipments.

The desired route will begin at Eq. 1 and will finish at Eq. 2. For a simplified explanation, we are supposing that all the resources are permanent and there is no failure into the network (the failed point will be outside this network). We are not describing the network type either, although the results are obtained mainly in an optical network, so we can consider that the ring is an optical ring.

The results obtained according to the different kinds of lookup will be:

- Lookup into a ring: In this topology, there would be no route between Eq. 1 and Eq. 2. The lookup should be between two equipments included into the ring: Eq A, Eq B, Eq C, Eq D, to obtain a valid result.
- Lookup among locations: in this case, the valid route would be between any equipment included in Loc 1 (Eq 1 and Eq 1') and any equipment included in Loc 2 (Eq 2 and Eq 2'), so there are two possible routes: crossing the ESS 1 or through equipments Eq F, Eq G and Eq H.
- Lookup among equipments: in this case, the only valid route would be between equipments Eq 1 and Eq 2, crossing the ring 1.

IV. RESULTS

The method has been applied over a huge network (more than 50,000 equipments) and to a wide range of cases varying the aforementioned parameters (route features and resource state). It has been verified that even the worst results in terms of lookup time mean a significant improvement compared to the non-optimized lookup. Telecommunication operators could efficiently solve most situations by means of this procedure.

The method has been applied over a huge network (more than 50,000 Equipments) and to a wide range of cases, defined by different signal types. In any signal type, we have varied:

- The route features;
- The boundary conditions and
- The resource special features.

It has been verified that even the worst results in terms of lookup time mean a significant improvement compared to the non-optimized lookup.

Each test has been defined following the process below:

- An origin and destination for the desired route are selected.
- A non-optimized lookup is carried out over the network.
- A signal type (route features) for the desired route is selected.
- An optimized lookup (taking into account only the route features) is processed.
- A set of variations is applied to all the boundary conditions for each origin and destination, showing different outcomes according to these variations.
- Start and finish time are stored for each lookup.

In Table 1, a summary of the results is shown to quantify the improvement. These results are obtained with six links as the maximum route length using as a 100-percent reference the time consumption for the non-optimized lookup, quantifying each result as a fraction of that time.

TABLE I. RESULT SUMMARY

Cases	Result
Maximum	63,46%
Minimum	28,13%
Average	52,63%

According to the input conditions, the lookup has been applied into the optical networks and through different networks. Results show that with different networks involved, the algorithm does not adapt so well to network features, but it improves the result too.

When the route length increases the improvement decreases very fast, and the lookup time is almost the same than in a general case, because in both of them, it grows exponentially, and the lookup is no useful in a practical way.

V. CONCLUSSIONS

The results show that taking into account not only geographical considerations as locations, but also data transmission network features, basically route continuity through equipments, the lookup times are significantly minor than the original ones.

The explained lookup, using the algorithm with the proposed restrictions, is efficient if the route length is moderated. This supposition is reasonable in many scenarios within the telecommunication operators' transmission network. When the necessary route length increases over the average (around six hops), the lookup time tends to pair the time it would be obtained if the lookup used an algorithm without restrictions.

As mentioned before, after the lookup obtains a route there is a validation where the algorithm checks if the route fulfills the special network features and boundary conditions. This step offers a good point to introduce new considerations into the algorithms, so that the route optimization can embody other objectives apart from the technical ones (for instance: economic costs or energy consumption).

REFERENCES

[1] L. R. Ford Jr. and D. R. Fulkerson (1962). "Flows in networks". Princeton University Press.

[2] D. Medhi and K. Ramasamy (2007). "Network routing: algorithms, protocols, and architectures". Morgan Kaufmann.

[3] J. Doyle and J. Carroll (2005). "Routing TCP/IP", Included in: *Volume I, Second Ed. Cisco Press*.

[4] N. Spring, R. Mahajan, and T. Anderson (2003). "Quantifying the causes of path inflation". Included in: *Proc. SIGCOMM 2003*.

[5] Gerald Ash (1997). "Dynamic routing in telecommunication networks". McGraw-Hill.

[6] M., A. Wainwright (2003). "Small road network". Included in: *I. Kennedy, Teletraffic Lecture Notes, School of Electrical and Information Engineering, University of the Witwatersrand, 2003*.

[7] Recommendation G.709/Y.1331: Interfaces for the optical transport network (OTN). ITU.

[8] M.L. Mouronte, R.M. Benito, J.P. Cárdenas, A. Santiago, V. Feliú, P. van Wijngaarden, and. L.G. Moyano (2009). "Complexity in spanish optical fiber and SDH transport networks". Included in: *Computer Physics Communications, Volume 180, Issue 4, April 2009*.

[9] N. Leeprechanon, P. Limsakul, and S. Pothiya (2010). "Optimal Transmission Expansion Planning Using Ant Colony Optimization". Included in: *Journal of Sustainable Energy & Environment 1 (2010)*.

[10] S. Bohacek, J. Hespanha, J. Lee, C. Lim, and K. Obraczka (2007). "Game Theoretic Stochastic Routing for Fault Tolerance and Security in Computer Networks". Included in: *IEEE Transactions on Parallel and Distributed Systems, Vol. 18, Issue 9, September 2007*.

[11] C. Fang, C. Feng, and X. Chen (2010). "A heuristic algorithm for minimum cost multicast routing in OTN network". Included in: *IEEE Xplore May 2010*.

Copyright (c) IARIA, 2011. ISBN: 978-1-61208-133-5