

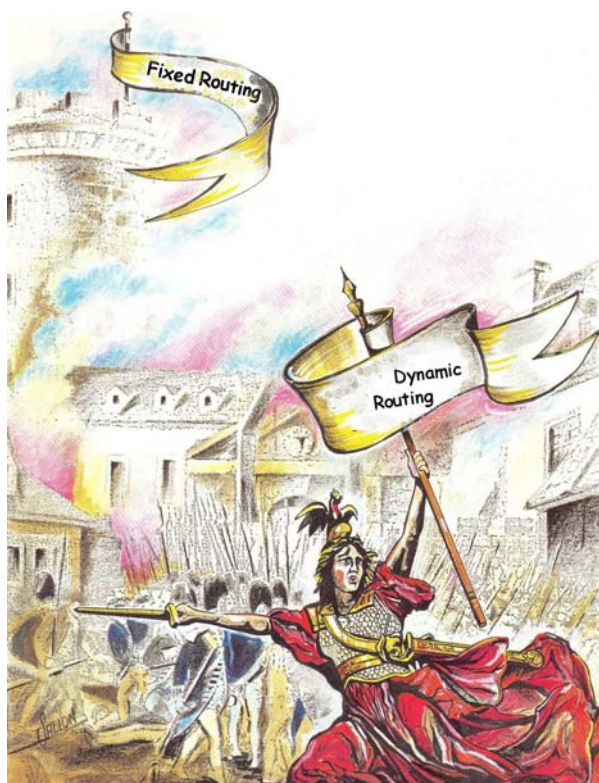
20 Years of Dynamic Routing in Circuit-Switched Networks: Looking backward to the Future

Gerald R. Ash, *IEEE Fellow*
AT&T

Prosper Chemouil, *IEEE Fellow*
France Telecom

1 Introduction

The 20th anniversary of the operational implementation of dynamic routing in circuit-switched networks, which occurred on 14 July 1984, represents a unique opportunity to look back on a subject that generated so much interest around the world and to analyze the influence of such studies in the design of new networks. It is first useful to recall the objectives of dynamic routing, to briefly describe the methods that were developed and to review the current status of these networks throughout the world. Since the 20th anniversary will occur on Bastille Day, this date marks the anniversary of two revolutions aiming at introducing more freedom and fairness: fortunately, the revolution that occurred two decades ago did not result in any chopped-off heads, as for the French one. Instead this paper represents a tribute to all scientists and engineers that took part in this Routing Revolution and who deserve hats off!



Routing Revolution on Bastille Day
(Design by A. Sallon, France Telecom R&D, 1989)

2. Background and Brief History

Hierarchical networks arose in the '40s and '50s with the development of common control switching systems that enabled the introduction of the alternate routing concept based on the overflow technique. As there were still technological limitations that required the guarantee of integrity between numbering, signalling, and routing, networks were structured into different levels used to concentrate traffic from one region to another. To prevent a call from returning to one of the switching centers along its routing path the call looping phenomenon overflowing and the selection of alternative paths were subject to hierarchical rules. In addition, due to limited measurement capabilities in the switches and lack of computing facilities, routing was determined at the design stage and remained fixed under normal conditions until the next design stage. Fixed hierarchical routing was then established, and is still used worldwide.

With the advent of digital switches, the emergence of common channel signalling systems, and the development of data networks, new processing capabilities allowed for the evolution of traffic routing from fixed hierarchical to flexible non-hierarchical. Substantial improvements in network cost efficiency and robustness result from the introduction of dynamic routing. Dynamic routing allows routing decisions adapt to load and network conditions. Studies have shown that significant economic and service benefits may accrue from implementing dynamic routing methods in national, private, or international networks, depending on the network structure and degree of connectivity of the network.

In fact the development of dynamic routing in circuit-switch networks has known several stages:

Genesis (1975-80): The possibility of flexible control of network traffic has given rise to the formulation of many theoretical problems. Among them, the real-time traffic routing has been commonly recognized as the most promising one. The early works concerned the traffic control concepts for networks with alternate routing [WEB], [GRA1], [NAK], [GIM]. But one of the first theoretical framework for dynamic routing was given in the mid-'70s by K. Narendra as he introduced the use of learning automata for telephone traffic routing [NAR]. A seminar given in 1975 by Narendra at Bell Laboratories led to concentrated effort by AT&T to study and eventually implement a DNHR network. This work was soon followed by various studies deriving new routing methods [HEN], [FOR].

Expansion Age (1979-1991): the rise of dynamic routing occurred in the late '80s, when Bell Northern Research (BNR), now part of Nortel Networks, set up a field trial in Toronto, Canada in 1979, based on periodic network state measurements [SZY]. At the same time, various research centres from network operators as well as from universities derived other proposals. It first resulted in the large-scale deployment of DNHR in AT&T's long distance network in 1984 [ASH1], followed by the STAR field trial in Paris metropolitan network by France Telecom in 1987 [GAU]. A local dynamic routing system was also implemented in Italcable switches for accessing the international network [DiB]. In the meantime, dynamic routing had been recognized as a major issue in the research community in telecommunications [CHE1]. This was completed by new proposals that were first introduced in the International Teletraffic Congresses – and then discussed in standardization bodies such as CCITT (now ITU-T). This Golden age was illustrated by various seminars and workshops [ITU], a Special issue of IEEE Communications Magazine that delivered a comprehensive status of dynamic routing methods [IEEE1], as well as the publication of ITU-T Recommendations that emphasized the importance of dynamic routing [E.170], [E.412], [E.525].

Maturity Age (1991- 2000): During this decade, many operators have implemented dynamic routing systems in their domestic network and international network. In particular, the WIN system which was initiated in the early 90's has been a unique initiative that gathered several international network operators [ASH2]. A second Special issue of IEEE Communications Magazine did focus on the main implementations [IEEE2], and several ITU Recommendations complemented the existing standards [E.350], [E.529].

Recession Age (from 2000): with emerging new technologies such as ATM and IP which are packet-oriented, the focus on TDM networks has rapidly decreased and the work did rather focus on similar principles of QoS and Routing applied to all network types [E.360]. It is expected that, with the deployment of IP-based networks, present dynamic routing systems will be progressively turned down and replaced with new ones implementing IP protocols.

3. Dynamic Routing Methods

When a call arrives at its originating switch (OS), the OS implementing the routing method executes the route selection rules associated with the routing table for the call to determine a route. In a routing method, the set of routes that can be assigned to the call may be altered according to a certain route set alteration rule. Depending on whether a switch functions as an OS, a via-switch (VS), or a destination switch (DS), different routing tables are used for calls. The OS normally determines the dynamic routing method used for a call and selects the appropriate routing table. A network is operated with progressive call control, originating call control, or a mix of the two control methods.

In a network with progressive call control, a switch selects a trunk group to an appropriate next switch. In a network with originating call control, the OS maintains control of the call. When crankback (or automatic rerouting (ARR)) is used, for example, at a via-switch (VS), the preceding switch maintains control of the call even if the calls are blocked at all the routes outgoing from the VS. In general, networks can operate with a mix of both control methods.

Routes in the routing table may consist of the direct trunk group, a two-trunk-group route through a single VS, or a multiple-trunk-group route through multiple VSs. To prevent network instability or to set up priorities between different types of calls, routes may be subject to Selective Circuit Reservation (SCR) restrictions [E.525] and [E.412]. SCR requires that one more than a specified number of circuits - the "reservation level" - are free on each trunk group before a route connection is allowed. This prevents calls that route on the direct OS-DS trunk group, for example, from being swamped by alternate routed multiple-trunk-group calls.

Traffic routing methods are categorized into the following four types based on their routing table category: fixed routing (FR), time-dependent routing (TDR), state-dependent routing (SDR), and event-dependent routing (EDR). We briefly introduce each of these methods in the next paragraphs [ASH3], and illustrated in Figure 1. Operational implementations are summarized in Table 1.

3.1. Fixed Routing (FR)

In a fixed routing (FR) method, a routing table is fixed for a call. Hierarchical or nonhierarchical routing structures may be realized based on fixed routing. In both hierarchical and non-hierarchical structures, the route set and route selection sequence are determined on a preplanned basis and maintained over a long period of time.

3.2 Time-Dependent Routing (TDR)

Time-dependent routing (TDR) methods are a type of dynamic routing in which the routing tables are altered at a fixed point in time during the day or week. TDR routing tables are determined on a preplanned basis and are implemented consistently over a time period. The TDR routing tables are determined considering the time variation of traffic load in the network. Typically, the TDR routing tables used in the network are coordinated by taking advantage of non-coincidence of busy hours among the traffic loads. DNHR is an example of TDR.

In TDR, the routing tables are preplanned and designed off-line using a centralized design system. The off-line computation determines the optimal routes from a very large number of possible alternatives, in order to minimize the network cost. The designed routing tables are loaded and stored in the various switches in the TDR network, and periodically recomputed and updated (e.g., every week) by the off-line system.

In this way, an OS does not require additional network information to construct TDR routing tables, once the routing tables have been loaded. This is in contrast to the design of routing tables in real time, such as in the state-dependent routing and event-dependent routing methods described below. Routes in the TDR routing table may consist of time varying routing choices and use a subset of the available routes. Routes used in various time periods need not be the same. Several TDR time periods are used to divide up the hours on an average business day and weekend into contiguous routing intervals, sometimes called load set periods.

Route selection rules employed in TDR routing tables, for example, may consist of simple sequential routing. In the sequential method all traffic in a given time period is offered to a single route set, and lets the first route in the route set overflow to the second route which overflows to the third route, and so on. Thus, traffic is routed sequentially from route to route, and the route set is allowed to change from hour to hour to achieve the preplanned dynamic, or time varying, nature of the TDR method. Other TDR route selection rules can employ probabilistic techniques to select each route in the route set and thus influence the realized flows.

3.3 State-Dependent Routing (SDR)

In state-dependent routing (SDR), the routes in the routing tables are altered automatically according to the state of the network. For a given SDR method, the routing table rules are implemented to determine the route choices in response to changing network status, and are used over a relatively short time period. Information on network status may be collected at a central processor or distributed to switches in the network. The information switch may be performed on a periodic or on-demand basis. SDR methods use the principle of routing calls on the best available route on the basis of network state information. For example, in the least loaded routing (LLR) method, residual capacity of the routes is calculated, and the route having the largest residual capacity is selected for the call. In general, SDR methods calculate a route cost for each call based on various factors such as the load-state or congestion state of trunk groups in the network. DCR, WIN, and RTNR are examples of SDR, which are illustrated later in this section.

In SDR, the routing tables are designed by the OS or a central routing processor (RP) with the aid of network information obtained through information switch with other switches and/or a centralized RP. There are various implementations of SDR distinguished by

- a) whether the computation of routing tables is distributed among the network switches or centralized and done in a centralized RP and,
- b) whether the computation of routing tables is done periodically or call by call.

This leads to three different implementations of SDR:

- a) Centralized periodic SDR – The centralized RP obtains trunk group status and traffic status information from the various switches on a periodic basis (e.g., every 10 seconds) and performs a computation of the optimal routing table on a periodic basis. To determine the optimal routing table, the RP executes a particular routing table optimization procedure such as LLR and transmits the routing tables to the network switches on a periodic basis (e.g., every 10 seconds). DCR is an example of centralized periodic SDR, as shown in Figure 1.
- b) Distributed periodic SDR – Each switch in the SDR network obtains trunk group status and traffic status information from all the other switches on a periodic basis (e.g., every 5 minutes) and performs a computation of the optimal routing table on a periodic basis (e.g., every 5 minutes). To determine the optimal routing table, the OS executes a particular routing table optimization procedure such as LLR. WIN is an example of distributed periodic SDR, as illustrated in Figure 1.
- c) Distributed call-by-call SDR – An OS in the SDR network obtains trunk group status and traffic status information from the DS, and perhaps from selected VSs, on a call by call basis and performs a computation of the optimal routing table for each call. To determine the optimal routing table, the OS executes a particular routing table optimization procedure such as LLR. RTNR is an example of distributed call-by-call SDR, as shown in Figure 1.

4.4 Event-Dependent Routing (EDR)

In event-dependent routing (EDR), the routing tables are updated locally on the basis of whether calls succeed or fail on a given route choice. In EDR, for example, a call is offered first to a fixed, pre-planned route often encompassing only a direct route, if it exists. If no circuit is available on the pre-planned routes, the overflow traffic is offered to a currently selected alternate route. If a call is blocked on the current alternate route choice, another alternate route is selected from a set of available alternate routes according to the given EDR routing table rules. For example, the current alternate route choice can be updated randomly, cyclically, or by some other means, and may be maintained as long as a call is established successfully on the route. Note that for either SDR or EDR, as in TDR, the alternate route may be changed in a time-dependent manner considering the time-variation of the traffic load. AMI, DAR, STR and LAW are examples of event-dependent routing, which are illustrated in Figure 1

In EDR, the routing tables are designed by the OS using network information obtained during the call setup function. Typically the OS first selects the direct trunk group and if that is busy then the current successful via route is tried. If the current successful via route is blocked, this condition is indicated by a busy OS-VS trunk group as determined by the OS or a

busy VS-DS trunk group as indicated by a release message sent from the VS to the OS. At that point the OS selects a new via route using the given EDR routing table design rules. Hence the routing table is constructed with the information determined during call setup, and no additional information is required by the OS. Figure 1 illustrates various implementations of Dynamic Routing methods.

4. Current implementations of Dynamic Routing

There are many operators who have implemented a dynamic routing method in their domestic network and international network. Table 1 summarizes the current

status of various dynamic routing systems that were implemented in several types of networks. As can be seen, many remain in full operation.

In addition to operational implementations, a great deal of work has been made either through field trials [CHA], [GAU], or introduction studies (that did not end positively) [CHE2], [GRA2], or even through academic research [DZI], [FIL], [GIB] [GIR], [KRI], [MAS2], [MIT]. The enormous bibliography that exists on this issue witnesses the huge impact that dynamic routing had on the telecommunications community during the last decade.

Table 1 – Status of Dynamic Routing Networks

Routing Type	Dynamic Routing Systems	Network	Start Year	End Year	Comments
TDR	DNHR <i>Dynamic Non-Hierarchical Routing</i>	AT&T US National Network	1984	1991	DNHR replaced by RTNR in 1991.
		AT&T FTS-2000 Network	1987	2002	DNHR replaced by RTNR in 2002.
SDR <i>centralized periodic</i>	GTAI <i>(GTAI is an Italian acronym: Management of the Traffic Transit Italcable switches)</i>	Italcable	1984	1985?	This routing mechanism was implemented between the 3 inter-continental switches operated by Italcable
		DCR <i>Dynamically Controlled Routing</i>	Stentor Canada National Network	1991	In operation
	Bell Canada Network		1992	In operation	Consists of one DCR network local to the Toronto area and one local to the Montreal area
	Sprint National Network		1994	In operation	
	MCI US National Network		1995	In operation	
	Qwest Communications National Network	1999	In operation		
SDR <i>distributed periodic</i>	WIN <i>Worldwide Intelligent network Routing</i>	Worldwide Intelligent Network	1993	In operation	WIN data is currently exchanged between AT&T/US, CHT-I/Taiwan and Alestra/Mexico.
SDR <i>distributed call-by-call</i>	RTNR <i>Real-Time Network Routing</i>	AT&T US National Network	1991	In operation	
		AT&T FTS-2000 Network	2002	In operation	
	RINR <i>Real-Time Internetwork Routing</i>	AT&T Global International Network	1991	In operation	
EDR	STR <i>State- and Time-dependent Routing</i>	NTT Japan National Network	1992	2002	The deployment of STR started in 1992, but operation stopped in 2002 when the D60 switches were replaced by new switches.
	DAR <i>Dynamic Alternative Routing</i>	British Telecom UK National Network	1993	?	
	STT <i>Success-To-the-Top network routing</i>	AT&T US National Network	1995	1999	STT is a method used for a period of time to route calls with voice enhancement devices in the path.
	LAW <i>Lastabhängige Automatische Wegesuche (in English, Automatic Last Choice Routing)</i>	Deutsche Telecom National Network	1995	In operation	LAW is implemented in the Transit Network as well as Regional and International Access networks).
	AMI <i>Acheminement Multiple Intelligent (in English, Multiple Intelligent Routing – MIR)</i>	France Telecom Long Distance Network	1998	In operation	AMI/MIR is an EDR system with multiple overflow routes and crankback.


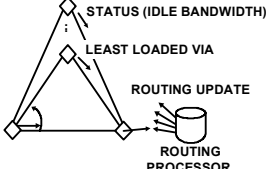
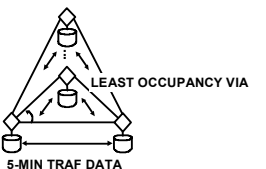
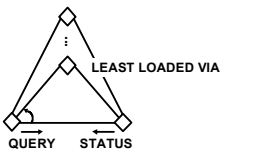
<p>EVENT DEPENDENT ROUTING (E.G. AMI, DAR, LAW/ODR)</p>		<ul style="list-style-type: none"> • SELECT PRIMARY PATH, THEN CURRENTLY SUCCESSFUL VIA PATH • RANDOMLY SELECT NEW VIA PATH WHEN CALL IS BLOCKED • OPTIONALLY ALLOW UP TO N CRANKBACKS TO FIND SUCCESSFUL VIA PATH (E.G., STT)
<p>STATE DEPENDENT ROUTING (CENTRALIZED, PERIODIC) (E.G. DCR)</p>		<ul style="list-style-type: none"> • SELECT PRIMARY PATH, THEN LEAST LOADED VIA PATH RECOMMENDED BY ROUTING PROCESSOR • EACH NODE SENDS PERIODIC LINK STATUS TO ROUTING PROCESSOR • EACH NODE RECEIVES PERIODIC ROUTING UPDATE FROM ROUTING PROCESSOR
<p>STATE DEPENDENT ROUTING (DISTRIBUTED, PERIODIC) (E.G., WIN)</p>		<ul style="list-style-type: none"> • PERIODIC (E.G., 5-MINUTE) TRAFFIC DATA EXCHANGE • SELECT PRIMARY PATH, THEN LEAST OCCUPANCY VIA PATH
<p>STATE DEPENDENT ROUTING (DISTRIBUTED, CALL-BY-CALL) (E.G. RTNR)</p>		<ul style="list-style-type: none"> • SELECT PRIMARY PATH, THEN LEAST LOADED VIA PATH BASED ON REAL-TIME STATUS • ORIGINATING NODE QUERIES TERMINATING NODE FOR LINK STATUS • ROUTING CHANGES CALL-BY-CALL

Figure 1. Implemented Dynamic Routing Methods

5. Application to Emerging Technologies

Much has been learned from these dynamic routing implementations, and the lessons and experience can be and have been carried forward as networks evolve to other technologies. Of course, some principles of dynamic routing were also implemented or analyzed in the framework of first generation data networks such as Arpanet and X.25. However, there are some key principles and lessons that are perhaps unique to "lessons learned" from circuit-switched dynamic routing, such as:

- a. use of "learning" or "event-dependent routing" (e.g., AMI, DAR, STR, LAW, etc.) as an alternative to state-dependent routing, whereas EDR avoids the potentially massive flooding of state information associated with some forms of SDR, to make networks more scalable,
- b. use of dynamic bandwidth reservation, to make networks more stable and efficient,
- c. use of class-of-service principles, to enable dynamic bandwidth allocation/protection for individual classes-of-service

Some of these principles have been extended to packet-based networks. They have been considered in ATM networks [AHM], [PNNI], and are also extendable to Traffic Engineering within IP-based MPLS networks, such as the analysis performed in [ASH5]. Current and future networks are rapidly evolving to carry a multitude of voice/ISDN services and packet data services on internet protocol (IP)-based networks, driven in part by the extremely rapid growth of IP-based data services. In this context, routing plays an essential role for meeting the QoS constraints that are inherent to the various services. The scope of dynamic routing methods includes the establishment of connections for narrowband, wideband, and broadband multimedia services within multiservice networks and between multiservice networks. Here a multiservice network refers to one in which various classes of service share the transmission, switching, management, and other resources of the network. There are quantitative performance requirements that the various classes of service normally are required to meet, such as end-to-end blocking, delay, and/or delay-jitter objectives. These objectives are achieved through a combination of dynamic routing, traffic management, and capacity management.

[ASH5] provides a performance analysis of lost/delayed traffic and control load for various dynamic routing methods, which control a network's response to traffic demands and other stimuli, such as traffic overloads, link failures, or node failures. Such methods have been analyzed in practice for TDM-based networks [ASH1], and in modeling studies for IP-based networks [ASH6, E.360]. Based on the results of these studies as well as established practice and experience, methods for dynamic routing and admission control are proposed for consideration in network evolution to IP-based technologies. In particular, we find that aggregated per-virtual-network bandwidth allocation compares favorably with per-flow allocation. We also find that event-dependent routing methods for management of label switched paths perform just as well or better than the state-dependent routing methods with flooding, which means that event-dependent routing path selection has potential to significantly enhance network scalability.

Awduche [AWD] gives an excellent overview of traffic engineering approaches for IP-based networks, and also provides traffic engineering requirements [RFC2702]. Crawley et al [RFC2386] provide good background and context for QoS routing in the Internet. A few early implementations of off-line, network-management-based traffic engineering approaches have been published, such as in the Global Crossing network [XIA] and Level3 network [SPR]. An intense activity is still going on in particular within IETF. Some studies have proposed more elaborate QoS routing and traffic engineering approaches in IP networks [APO], [ELW] and [MA], [OUE]. More recently, an adaptive routing method based on load sharing updated periodically has been proposed [GOJ]. However, sophisticated, on-line, QoS routing and traffic engineering methods widely deployed in TDM networks have yet to be extended to IP-based networks. Vendors have yet to announce full traffic engineering capabilities in their products. Network operator interest is also tempered by the current practice of over-provisioning IP networks, with concomitant low utilization and efficiency [ODL]. Anyway there is still an opportunity for increased profitability and performance in such networks through application of dynamic routing methods. The experience obtained in TDM networks obviously provides a comprehensive knowledge for introducing dynamic routing in large scale IP-based networks. Still much remains to be done...

6. Acknowledgements

The authors owe a debt of gratitude to the many esteemed colleagues who were kind enough to provide information contained in this paper. These people include Dave Allan (Nortel), Joyce Bradley (Nortel), Suching Chou (AT&T), Joachim Dressler (Deutsche Telekom), Frank Kelly (Cambridge University), Peter Key (Microsoft), Christopher Kwan (AT&T), Kenichi Mase (Niigata University), Deep Medhi (University of Missouri, Kansas City), Joyce Migdall (AT&T), Arne Oestlie (Telenor), Manuel Villén-Altamirano (Telefonica) and Ben Vos (Sprint).

7. Bibliography

The bibliography hereafter is not comprehensive but provides a good illustration of the intense activity that was produced on dynamic routing. Key contributors on dynamic routing have been cited through little part of their work. We regret not to be able to mention all the publications or the experts who have devoted research on dynamic routing.

- [AHM] Ahmadi, H. et al: "*Dynamic Routing and Call Control in High-Speed Integrated Networks*", Proc. of Int'l Teletraffic Congress, ITC 13 Copenhagen, Denmark, 1991.
- [APO] Apostolopoulos, G.: "*Intra-Domain QoS Routing in IP Networks: A Feasibility and Cost/Benefit Analysis*", IEEE Network, September 1999.
- [ASH1] Ash G.R., Cardwell R.H., Murray R.P.: "*Design and Optimization of Networks with Dynamic Routing*", Bell syst. Tech. J., Vol. 60, n°8, 1981.
- [ASH2] Ash G.R., Chemouil P., Kashper A.N., Katz S.S., Watanabe Y.: "*Robust Design and Planning of a Worldwide Intelligent Network*", IEEE J. on Selected. Areas in Commun., Vol. 7, n°8, 1989.
- [ASH3] Ash, G.R.: "*Dynamic Routing in Telecommunications Networks*", McGraw-Hill, 1998.
- [ASH4] Ash G.R et al.: "*Real-Time Network Routing in a Dynamic Class-of-Service Network*", Proc. of Int'l Teletraffic Congress, ITC 13, Copenhagen, Denmark, 1991.
- [ASH5] Ash G.R.: "*Performance Evaluation of QoS-Routing Methods for IP-Based Multiservice Networks*", Computer Communications Magazine, July 2003, <http://www.research.att.com/~jrex/jerry/>.
- [ASH6] Ash, G.R. et al: "*Routing Evolution in Multiservice Integrated Voice/Data Network*", Proc. of Int'l Teletraffic Congress, ITC 16, Edinburgh, UK, 1999.
- [AWD] Awduche, D.: "*MPLS and Traffic Engineering in IP Networks*", IEEE Com. Magazine, Vol. 17, n°12, 1999.
- [CHA] Chaudhary V.P., Krishnan K.R., Pack C.D.: "*Implementing Dynamic Routing in the Local Telephone Companies of the USA*", Proc. of Int'l Teletraffic Congress, ITC 13, Copenhagen, Denmark, 1991.
- [CHE1] Chemouil P., J. Filipiak J., Gauthier P.: "*Analysis and Control of Traffic Routing in Circuit-Switched Networks*", Comp. Networks and ISDN Syst., Vol. 11, n°3, 1986.
- [CHE2] Chemouil P., Lebourges M., Gauthier P.: "*Performance Evaluation of Adaptive Traffic Routing in a Metropolitan Network: A Case Study*", Proc. Globecom '89, Dallas, TX, 1989.
- [DiB] DiBenedetto A., LaNave P., Sisto C.: "*Dynamic Routing of the Italcable Telephone Traffic: Experience and Perspectives*", Proc. Globecom '89, Dallas, TX, 1989.
- [DZI] Dziong Z., Pioro M., Körner U.: "*State-Dependent Routing in Circuit-switched Networks: A Maximum Reward Approach*", Proc. of Int'l Teletraffic Congress, ITC 12, Turin, Italy, 1988.

- [E.170] ITU-T Recommendation: "*Traffic Routing Principles*", Geneva, 1988, rev.1992, rev. 1997.
- [E.350] ITU-T Recommendation E.350 "Dynamic Routing Interworking", Geneva, 1988, rev.1992
- [E.360] ITU-T Recommendation: "*QoS Routing & Related Traffic Engineering Methods for Multiservice TDM-, ATM-, & IP-Based Networks*", Geneva, 1997.
- [E.412] ITU-T Recommendation: "*Network Management Controls*", Geneva, 1988, rev.1992, rev. 1996.
- [E.525] ITU-T Recommendation: "*Designing Networks to Control Grade of Service*", Geneva, 1988.
- [E.529] ITU-T Recommendation: "*Network dimensioning using end-to-end GOS objectives*", Geneva, 1997
- [ELW] Elwalid A. et al: "*MATE: MPLS Adaptive Traffic Engineering*", Proc. Infocom '01, April 2001.
- [FIL] Filipiak J.: "*Modelling and Control of Dynamic Flows in Networks*", Springer Verlag, 1988.
- [FOR] Forestier J.P.: "*A Decentralized Approach for Real-Time Adaptive Control of Telecommunications Networks*", Proc. Networks '80, Paris, France, 1980.
- [GAU] Gauthier P., Chemouil P.: "*A system for Testing Adaptive Traffic Routing in France*", Proc. Globecom '87, Tokyo, Japan, 1987.
- [GIM] Gimpelson L.A.: "*Network Management: Design and control of Communications Networks*", Elect. Commun., Vol. 49 n°1, 1974
- [GIB] Gibbens R.J, Kelly F.P., Key P.B.: "*Dynamic Alternative Routing: Modeling and Behavior*", Proc. of Int'l Teletraffic Congress, ITC 12, Turin, Italy, 1988.
- [GIR] Girard A.: "*Routing and Dimensioning in Circuit-Switched Networks*", Addison Wesley, 1990.
- [GOJ] Gojmerac I.: "*Routing and traffic engineering for future IP networks*", COST 279 Meeting, Rome, Italy, 2004
- [GRA1] Grandjean Ch.: "*Call Routing Strategies in Telecommunications Networks*", Proc. of Int'l Teletraffic Congress, ITC 5, New-York, USA, 1967.
- [GRA2] Granel E. et al.: "*A Comparative Study of several Dynamic Routing Algorithms with Adaptive Pre-selection and Selection Phase*", Proc. of Int'l Teletraffic Congress, ITC 13 Copenhagen, Denmark, 1991.
- [HEN] Hennion B.: "*Feedback Methods for Calls Allocation on the Crossed Traffic Routing*", Proc. of Int'l Teletraffic Congress, ITC 9, Torremolinos, Spain, 1979.
- [IEEE1] Special Issue: "*Advanced Traffic Control Methods for Circuit-Switched Telecommunications Networks*", IEEE Com. Mag., Vol.28 n°10, 1990.
- [IEEE2] Special Issue: "*Dynamic Routing in Telecommunications Networks*", IEEE Com. Mag., Vol.33 n°7, 1995.
- [ITU] ITU/UNDP Seminar on *Intelligent Routing Strategies including Network Management aspects*, Zruc, Czechoslovakia, 1986
- [KRI] Krishnan K.R., Ott T.: "*State-Dependent Routing for Telephone Traffic: Theory and Results*", Proc. CDC '86, Athens, Greece, 1986.
- [MA] Ma Q., Steenkiste P.: "*Routing Traffic with Quality-of-Service Guarantees in Integrated Services Networks*", Proc. of NOSSDAV '98, 1998.
- [MAS1] Mase A., Yamamoto H.: "*Advanced Traffic Control Methods for Network Management*", IEEE J. on Selected. Areas in Commun., vol. 7, n° 8, 1989.
- [MAS2] Mason L.G., Girard A.: "*Control Techniques and Performance Models for Circuit-Switched Networks*", Proc. CDC '82, Orlando, FL, 1982.
- [MIT] Mitra D., Seery J.B.: "*Comparative Evaluations of Randomized and Dynamic Routing Strategies for Circuit-Switched Networks*", IEEE Trans. on Communications, pp. 102-116, January, 1991.
- [NAK] Nakagome Y., Mori H.: "*Flexible Routing in the Global Communication Network*", Proc. of Int'l Teletraffic Congress, ITC 7, Stockholm, Sweden, 1973.
- [NAR] Narendra K.S., Wright E.A., Mason L.G.: "*Applications of Learning Automata to Telephone Traffic Routing and Control*", IEEE Trans. SMC, Vol. 7 n° 11 1977.
- [ODL] Odlyzko, A.: "*Data Networks are Lightly Utilized, and will Stay that Way*", The Review of Network Economics, Vol. 2, n° 3, September 2003
- [OUE] Oueslati S., Roberts J.W.: "*Application of Trunk Reservation to Elastic Flow Routing*", Proc. of IFIP Networking 2000, Paris, France, 2000.
- [PNNI] ATM Forum: "*Private Network-Network Interface Specification Version 1.1 (PNNI 1.1)*", April 2002
- [REG] Regnier J., Cameron W.H.: "*State-Dependent Dynamic Traffic Management for Telephone Networks*", IEEE Com. Mag, Vol.28 n°10, 1990.
- [RFC2386] Crawley E., Nair F., Rajagopalan B., Sandick H.: "*A Framework for QoS-Based Routing in the Internet*", August 1998.
- [RFC2702] Awduche D. et al: "*Requirements for Traffic Engineering over MPLS*", IETF, September 1999
- [SPR] Springer V. et al: "*Level3 MPLS Protocol Architecture*", Work in progress.
- [STA] Stacey R.R., Songhurst D.J.: "*Dynamic Alternative Routing in the British Telecom Trunk Network*", Proc. ISS'87, Phoenix, AZ, 1987.
- [SZY] Szybicki E., Bean A.E.: "*Advanced Traffic Routing in Local Telephone Network: Performance of Proposed Call Routing Algorithms*", Proc. of Int'l Teletraffic Congress, ITC 9, Torremolinos, Spain, 1979.
- [WEB] Weber J.H.: "*Some Characteristics of Communications Networks with Automatic Alternate Routing*", Bell Syst. Tech. Journal Vol. 41 n° 2, 1965.
- [XIAO] Xiao, X. et al: "*Traffic Engineering with MPLS in the Internet*", IEEE Network, March 2000.