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SERIES E: OVERALL NETWORK OPERATION, TELEPHONE SERVICE, SERVICE OPERATION AND HUMAN FACTORS

Operation, numbering, routing and mobile services – ISDN provisions concerning users

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Dynamic Routing Interworking

ITU-T Recommendation E.350

(Previously CCITT Recommendation)

ITU-T E-SERIES RECOMMENDATIONS

OVERALL NETWORK OPERATION, TELEPHONE SERVICE, SERVICE OPERATION AND HUMAN FACTORS

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ITU-T RECOMMENDATION E.350

DYNAMIC ROUTING INTERWORKING

Summary

This Recommendation gives a framework for dynamic routing interworking in circuit-switched PSTN, narrow-band ISDN, and broadband ISDN networks. It illustrates the functionality for setting up a call from an originating exchange in one network to a destination exchange in another network, using one or more dynamic routing methods in conjunction possibly with fixed routing. It describes:

a) relevant dynamic routing functions for TDR, SDR, and EDR networks;

b) information flows required for dynamic routing interworking between exchanges; and

c) several examples of interworking between different dynamic routing methods.

Source

ITU-T Recommendation E.350 was prepared by ITU-T Study Group 2 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on 13 March 2000.

FOREWORD

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NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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DYNAMIC ROUTING INTERWORKING

(Geneva, 2000)

1 Introduction

There are many operators who have implemented a dynamic routing method in their domestic network and international network. The dynamic routing methods in use are variants of time-dependent routing (TDR), state-dependent routing (SDR), and event-dependent routing (EDR) methods. An international or inter-operator call will traverse more than one network, and hence may be routed end-to-end using more than one routing method. In the interconnecting network, different dynamic routing methods in conjunction with fixed routing may be in use. This Recommendation covers the interworking of different types of routing methods in non-hierarchical networks, in order to complete a call originating in one switch and terminating in another, where the originating, via, and terminating switches may have implemented different routing methods.

Substantial improvements in telephone network cost efficiency and robustness result from the introduction of dynamic routing. Dynamic routing envisions that routing decisions adapt to load and network conditions, and that distributed, originating switch call control can be used. Dynamic routing methods may incorporate existing traffic routing features such as automatic rerouting and existing network management features such as circuit reservation. Dynamic routing methods must interwork with existing routing methods such as fixed routing. A framework is needed to guarantee unrestricted interworking of different dynamic routing methods, perhaps implemented on different vendor equipment, for routing between network operators, national as well as international. Standardization of information flows is needed, so that switching equipment from all different vendors can interwork to implement dynamic routing methods in a coordinated fashion.

Hierarchical routing is in widespread use throughout the world for national networks, private networks, and international networks interconnecting national networks. 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. It is desirable that a maximal set of dynamic routing techniques be enabled, which should include all dynamic routing methods in use in public networks today. All currently implemented and new dynamic routing methods of PSTN/ISDN networks should be supported by this approach, which include distributed adaptive dynamic routing (DADR), dynamic alternate routing (DAR), dynamically controlled routing (DCR), dynamic non-hierarchical routing (DNHR), optimized dynamic routing (ODR), real-time network routing (RTNR), state- and time-dependent routing (STR), and worldwide intelligent network (WIN) dynamic routing.

2 Scope

This Recommendation gives a framework for dynamic routing interworking in circuit-switched PSTN, narrow-band ISDN, and broadband ISDN networks. It illustrates the functionality for setting up a call from an originating exchange in one network to a destination exchange in another network, using one or more dynamic routing methods in conjunction possibly with fixed routing. It describes:

a) relevant dynamic routing functions for TDR, SDR, and EDR networks;

b) information flows required for dynamic routing interworking between exchanges; and

c) several examples of interworking between different dynamic routing methods.

This Recommendation is trying to enable *any* routing method to be implemented by a network operator and interwork with other different routing methods in various exchanges. As such, the Recommendation is *not* trying to standardize any particular routing method. For those information flows requiring information exchange specific for dynamic routing, the information exchange needs are identified.

3 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

– CCITT Recommendation E.170 (1992), *Traffic routing*.

– ITU-T Recommendation E.177 (1996), *B-ISDN routing*.

– ITU-T Recommendation E.351 (2000), *Routing of multimedia connections across TDM-, ATM- and IP-based networks.*

– ITU-T Recommendation E.411 (1998), *International network management – Operational guidance*.

– ITU-T Recommendation E.412 (1998), *Network management controls*.

– ITU-T Recommendation Q.71 (1993), *ISDN circuit mode switched bearer services*.

4 Definitions

This Recommendation defines the following terms:

4.1 Circuit group: A group of circuits which is engineered as a unit.

4.2 Circuit group classmark: A data item assigned administratively at an exchange to a circuit group for evaluation by a routing table.

4.3 Destination exchange: Terminating exchange within a given dynamic routing network.

4.4 Exchange: A switching centre.

4.5 O-D pair: An originating exchange to destination exchange pair for a given traffic stream.

4.6 Originating exchange: Originating exchange within a given dynamic routing network.

4.7 Route: A concatenation of circuit groups providing a connection between an O-D pair.

4.8 Route set: A set of routes connecting the same O-D pair.

4.9 Routing table: A route set and rules to select one route out of the set for a traffic stream.

4.10 Traffic stream: A class of calls with the same traffic characteristics.

4.11 Via exchange: A via exchange within a given dynamic routing network.

5 Abbreviations

This Recommendation uses the following abbreviations:

AAR	Automatic Alternate Routing
ARR	Automatic Rerouting
B-ISDN	Broadband Integrated Services Digital Network
CB	Crankback
CCS	Common Channel Signalling
CP-SDR	Centralized Periodic State-Dependent Routing
CR	Circuit Reservation
DADR	Distributed Adaptive Dynamic Routing
DAR	Dynamic Alternate Routing
DCR	Dynamically Controlled Routing
DC-SDR	Distributed Call-by-Call State-Dependent Routing
DE	Destination Exchange
DNHR	Dynamic Non-hierarchical Routing
DP-SDR	Distributed Periodic State-Dependent Routing
EDR	Event-Dependent Routing
FR	Fixed Routing
GOS	Grade of Service
LLR	Least Loaded Routing
N-ISDN	Narrow-band Integrated Services Digital Network
ODR	Optimized Dynamic Routing
OE	Originating Exchange
PNNI	Private Network-to-Network Interface
PSTN	Public Switched Telephone Network
RECOM	recommendation
RES	Reservation
RP	Routing Processor
RTNR	Real-Time Network Routing
SDR	State-Dependent Routing
STR	State- and Time-Dependent Routing
TDR	Time-Dependent Routing
VE	Via Exchange
VDL	Via and Destination Exchange List
WIN	Worldwide Intelligent Network (Routing)

6 Routing methods

A specific traffic routing method is characterized by the structure of the routing table used in the method. The routing table consists of a route set and rules to select one route out of the route set for a given traffic stream. When a call in a traffic stream arrives at its originating exchange (OE), the OE implementing the routing method executes the route selection rules associated with the routing table for the call to determine a route among the routes in the route set for the traffic stream. In a routing method, the set of routes that can be assigned to the call stream may be altered according to a certain route set alteration rule. Depending on whether an exchange functions as an OE, a via exchange (VE), or a destination exchange (DE), different routing tables are used for calls. The OE normally determines the dynamic routing method used for a call and selects the appropriate routing table. At the VE and TE, however, a fixed routing table is normally used and not a dynamic 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, an exchange selects a circuit group to an appropriate next exchange. In a network with originating call control, the OE maintains control of the call. If crankback [or automatic rerouting (ARR)] is used, for example, at a via exchange (VE), the preceding exchange maintains control of the call even if the calls are blocked at all the routes outgoing from the VE. In general, networks can operate with a mix of both control methods.

In ITU-T Recommendations E.170 and E.177, 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 discuss each of these methods in the following subclauses.

In Annex A we give specific examples of the TDR, SDR, and EDR methods discussed below, and present eight dynamic routing functional descriptions for implemented dynamic routing methods. These examples illustrate dynamic routing functions occurring at the OE, VE, and DE, and various information flows in executing these dynamic routing functions. A TDR example is given in Figure A.1 for the case of dynamic non-hierarchical routing (DNHR). A centralized periodic SDR example is given in Figure A.2 for the case of dynamically controlled routing (DCR). A distributed periodic SDR example is given in Figure A.3 for the case of worldwide intelligent network (WIN) dynamic routing. A distributed call-by-call SDR example is given in Figure A.4 for the case of real-time network routing (RTNR). Four examples of EDR are given in Figures A.5, A.6, A.7 and A.8, for the cases of dynamic alternate routing (DAR), state- and time-dependent routing (STR), distributed adaptive dynamic routing (DADR), and optimized dynamic routing (ODR), respectively. It should be noted that Annex A describes illustrative examples of proprietary routing methods, many of which are protected by intellectual property, but their inclusion in Annex A should not be construed as a recommendation of these specific methods in any way.

Note that the descriptions of FR, TDR, SDR, and EDR in this clause, in E.170, and in Annex A are all examples of routing methods. Since specific implementations of FR, TDR, SDR, and EDR can vary, these examples should not be construed as contradicting each other in any way.

6.1 Fixed Routing (FR)

In a fixed routing (FR) method, a routing table is fixed for a traffic stream. Hierarchical or non-hierarchical routing structures may be realized based on fixed routing, as described in Recommendation E.170. In both hierarchical or non-hierarchical structures, the route set and route selection sequence are determined on a preplanned basis and maintained over a long period of time.

6.2 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 streams. DNHR is an example of TDR, which is illustrated in Annex A.

In TDR, the routing tables are preplanned and designed off-line using a centralized design system, which employs the TDR network design model. The off-line computation determines the optimal route sets 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 exchanges in the TDR network, and periodically recomputed and updated (e.g. every week) by the off-line system. In this way an OE 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. Route sets 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.

Routes in the TDR routing table may consist of the direct circuit group, a two-circuit-group route through a single VE, or a multiple-circuit-group route through multiple VEs. Routes in the routing table may be subject to circuit reservation (CR) restrictions, such as those described in Recommendation E.412. CR requires that one more than a specified number of circuits – the "reservation level" – are free on each circuit group before a route connection is allowed. This prevents calls that route on the direct OE-DE circuit group, for example, from being swamped by alternate routed multiple-circuit-group calls. Note that the use of circuit reservation in path selection is an option at the discretion of a network operator.

6.3 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 exchanges in the network. The information exchange 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 for respective traffic streams 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 traffic stream based on various factors such as the load-state or congestion state of circuit groups in the network. DCR, WIN, and RTNR are examples of SDR, which are illustrated in Annex A.

In SDR, the routing tables are designed by the OE or a central routing processor (RP) with the aid of network information obtained through information exchange with other exchanges 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 exchanges 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 – Here the centralized RP obtains circuit group status and traffic status information from the various exchanges on a periodic basis (e.g. every ten 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 exchanges on a periodic basis (e.g. every ten seconds). DCR is an example of centralized periodic SDR, as illustrated in Annex A.

b) Distributed periodic SDR – Here each exchange in the SDR network obtains circuit group status and traffic status information from all the other exchanges on a periodic basis (e.g. every five minutes) and performs a computation of the optimal routing table on a periodic basis (e.g. every five minutes). To determine the optimal routing table, the OE executes a particular routing table optimization procedure such as LLR. WIN is an example of distributed periodic SDR, as illustrated in Annex A.

c) Distributed call-by-call SDR – Here an OE in the SDR network obtains circuit group status and traffic status information from the DE, and perhaps from selected VEs, 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 OE executes a particular routing table optimization procedure such as LLR. RTNR is an example of distributed call-by-call SDR, as illustrated in Annex A.

Routes in the SDR routing table may consist of the direct circuit group, a two-circuit-group route through a single VE, or a multiple-circuit-group route through multiple VEs. Routes in the routing table may be subject to CR restrictions.

6.4 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, preplanned route often encompassing only a direct route, if it exists. If no circuit is available on the preplanned 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 for the traffic stream 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 set for a traffic stream may be changed in a time-dependent manner considering the time-variation of the traffic load. DAR, DADR, ODR, and STR are examples of event-dependent routing, which are illustrated in Annex A.

In EDR, the routing tables are designed by the OE using network information obtained during the call setup function. Typically the OE first selects the direct circuit 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 OE-VE circuit group as determined by the OE or a busy VE-DE circuit group as indicated by a release message sent from the VE to the OE. At that point the OE 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 OE. Routes in the EDR routing table may consist of the direct circuit group, a two-circuit-group route through a single VE, or a multiple-circuit-group route through multiple VEs. Routes in the routing table may be subject to CR restrictions.

7 Interworking of different routing methods

When introducing dynamic routing into exchanges of international and inter-operator networks, several interworking cases have to be investigated. This will encompass interworking of fixed routing with dynamic routing methods as well as the interworking of different dynamic routing methods.

7.1 General interworking requirements for non-hierarchical routing in meshed networks

This subclause summarizes the general interworking requirements for non-hierarchical routing, which apply both to fixed routing and dynamic routing.

7.1.1 Two-link routing

In meshed networks with non-hierarchical routing, alternate routes are often restricted to two-circuit group routes. There are several reasons for this. First, two-circuit-group routing is often nearly as efficient as routing methods which allow longer routes. Second, it is somewhat easier to prevent circular routing. Third, restricting routes to at most two circuit groups helps to prevent degradation of network performance under network overload.

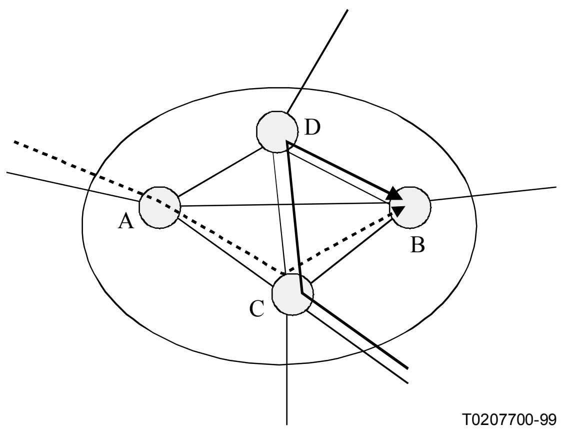


Figure 1/E.350 – Traffic streams with same destination exchange B but with different originating exchanges, which must be routed differently by exchange C

Two-link routing requires that each exchange is capable of distinguishing between traffic streams originating in one exchange from traffic streams incoming from other exchanges in the network. In the example of Figure 1, exchange C may route traffic streams originating in its served area indirectly, for example via exchange D, to exchange B (full line). However, traffic streams incoming from exchange A must be directly routed to exchange B (dashed line) and must not be routed via exchange D to optimize the two-link requirement.

Exchange C may distinguish between these two different traffic streams based on different screening classmarks of circuit groups incoming from other exchanges of the non-hierarchical routing network, on one hand, and of circuit groups incoming from exchanges of the served area, on the other hand. In this case no specific information exchange is required between exchanges. Alternatively, the originating exchange (e.g. A) may use a specific forward indicator when setting up a call for non-hierarchical routing. Based on this forward indicator, a via exchange (e.g. C) is able to distinguish between both traffic streams. Use of either the screening classmark method or this forward indicator between two exchanges requires bilateral agreement between the respective network operators. Note that while some of the dynamic routing methods described in Annex A make use of the former solution based on circuit group screening classmarks, others use the latter solution based on specific forward indicators.

7.1.2 Interworking with selective circuit reservation

Figure 2 shows three types of traffic streams carried by a circuit group (e.g. from A to B) in a non-hierarchical routing network:

1) Directly routed traffic from originating exchange A to destination exchange B.

2) Incoming traffic to exchange A from other originating exchanges (e.g. C) of the non-hierarchical routing network which also is directly routed by originating exchange A to destination exchange B.

3) Incoming traffic from the served area of exchange A which is indirectly routed via exchange B to another destination exchange in the non-hierarchical routing network (e.g. C).

To prevent degradation of network performance under high network load, directly routed calls between an originating exchange and destination exchange should be preferred to indirectly routed calls on circuit group A to B. This may be achieved by an appropriate application of selective circuit reservation control to circuit groups, as defined in Recommendation E.412. However, for this purpose exchange A must be able to distinguish between the different types of traffic streams. Exchange A may distinguish between traffic streams of type 1 (e.g. A to B) and 2 (e.g. C via A to B) based on different screening classmarks of circuit groups incoming from other exchanges of the non-hierarchical routing network, on one hand, and of circuit groups incoming from exchanges of the served area, on the other hand. By evaluating the traffic attribute "alternate routed traffic", as described in Recommendation E.412, exchange A is also able to identify the traffic streams of type 3, which originate in the served area of exchange A and are indirectly routed via exchange B towards the destination exchange (e.g. A via B to C). Note, that in this particular implementation no specific information exchange is required between exchanges when evaluating circuit group classmarks and traffic attributes for routing.

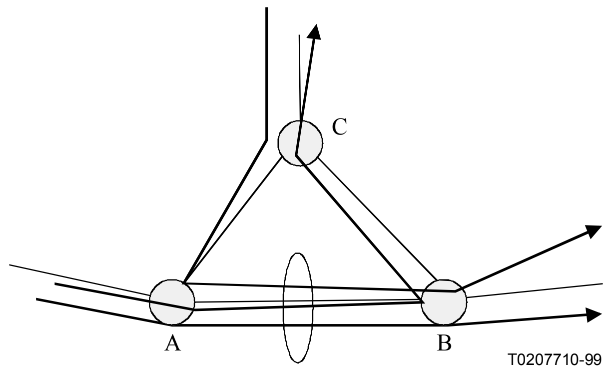


Figure 2/E.350 – Circuit Group A to B carries three types of traffic streams

Alternatively, the originating exchange may use a specific forward indicator for application of an appropriate selective circuit reservation control, when setting up a call for non-hierarchical routing. For example, when in Figure 2 exchange C sets up a call for alternate routing via exchange A to exchange B, a forward indicator may be included by exchange C which denotes to exchange A that selective circuit reservation should be applied on the outgoing circuit group for the call. Use of screening classmarks on circuit groups of this forward indicator between exchanges requires bilateral agreement between the respective network operators. Note that while some of the dynamic routing methods described in Annex A make use of former solution based on circuit group classmarks and traffic attributes, others use the latter solution based on a forward indicator.

7.1.3 Interworking with automatic rerouting (Crankback)

Automatic rerouting (crankback) is defined in Recommendation E.170 and may also be applied to exchanges using dynamic or fixed non-hierarchical routing. Note that some of the dynamic routing methods described in Annex A make use of specific backward indicators as described in Recommendation E.170 for control of automatic rerouting.

7.2 Interworking of a dynamic routing method with fixed routing

This subclause identifies the interworking capabilities between fixed and different dynamic routing methods without imposing specific information exchange requirements to all exchanges.

These interworking capabilities are of special importance for any strategy which introduces dynamic routing into existing heterogeneous networks, e.g. like the international and other inter-operator networks. A single step introduction of dynamic routing into all exchanges is usually not possible. During a considerable transition time, fixed routing in some exchanges must be interworked with dynamic routing being introduced into other exchanges.

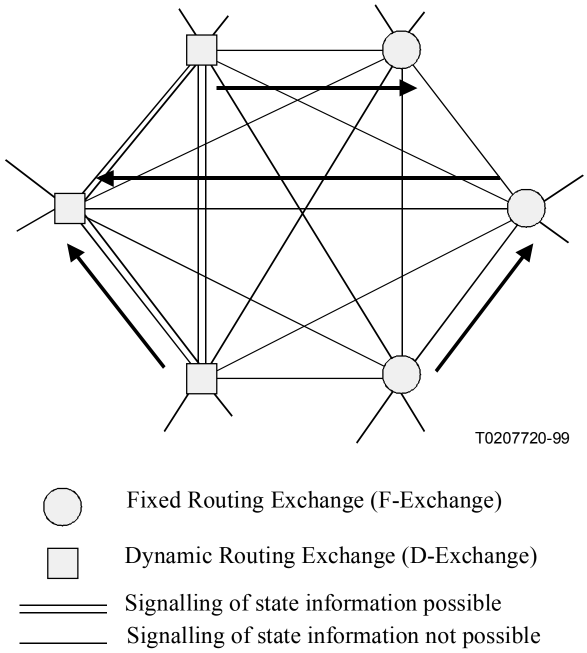


Figure 3/E.350 – Interworking scenario between fixed routing and a single dynamic routing method

Figure 3 shows schematically the interworking scenarios that are discussed in this subclause. Within a meshed network, dynamic routing capability is introduced into some exchanges denoted in Figure 3 as D-exchanges. All other exchanges stay with their fixed routing methods, which are denoted in Figure 3 as F-exchanges, and do not support specific information exchange for dynamic routing. The bold arrows represent the four different types of O-D pairs. Double lines indicate the possibility of exchanging state information, if required by the dynamic routing method. For simplicity it is assumed in this subclause that the same dynamic routing method is deployed in all the D-exchanges. Interworking of different dynamic routing methods is discussed in 7.3. Depending on the O-D pair, routing restrictions may result. With respect to the possible originating exchange-to-destination exchange pairs (O-D pairs), four cases have to be distinguished (see arrows in Figure 3).

Case 1: *F- to F-exchanges* – The originating F-exchange will continue to use fixed routing. Calls are routed on the direct circuit group if circuits are available. Alternate routes may have an F-exchange or a D-exchange as a via exchange. D-type via exchanges must be able to perform the fixed routing method when serving as a via exchange. A D-type via exchange must be able to evaluate circuit group screening classmarks to guarantee two-link routing in order to interwork with F-exchanges not supporting specific forward indicators.

Case 2: *F- to D-exchanges* – Same as F- to F-exchanges.

Case 3: *D- to F-exchanges* – Depending on the dynamic routing method being deployed in the originating D-exchange, routing restrictions may result for the originating D-exchange. Figure 4 shows that the states of some circuit groups may remain unknown to exchanges using SDR methods, whether they are centralized SDR methods or distributed SDR methods. Therefore the originating D-exchange may be forced to use for the direct circuit group overflow traffic only other D-exchanges as via exchanges, because only in this case full state-information may be available for the alternate route.

Hybrid SDR/EDR-methods use state-information for those circuit groups for which it is available and monitor the congestion of the other groups by evaluating congestion events as EDR methods do. In this way the D-exchange may use any other exchange as a via exchange for the direct circuit group overflow traffic, and in that case there are no routing restrictions on via exchanges. Some distributed SDR methods may rely on receiving state-information from the destination exchange. In this case the originating exchange may use a hybrid SDR/FR or SDR/TDR method, in which FR or TDR is used to a destination F-exchange.

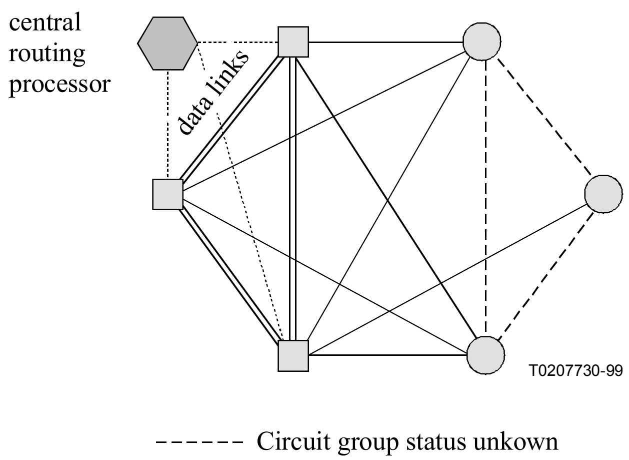


Figure 4/E.350 – Some link states remain unknown to state dependent routing exchanges

If the originating D-exchange is using an EDR method, no routing restrictions result from missing state information. This is because EDR methods adapt to the prevailing network load situation using trial and error approaches. Therefore EDR methods are not dependent on receiving explicit circuit group status information from other exchanges of the network.

Case 4: *D- to D-exchanges* – No interworking restrictions result for the known dynamic routing methods. This is because for these O-D pairs, circuit group status information will be available for both circuit groups of the two-circuit group alternate routes (by a centralized routing processor or by the exchange of status information between the D-exchanges). However, note that a D-exchange may not use specific forward indicators or any other specific information exchange for call control on an alternate route via an F-exchange, which does not support this specific information. Table 1 summarizes the above four cases wherein it is assumed that there are no routing restrictions imposed by the VE or TE capabilities.

Table 1/E.350 – Routing at the originating exchange with dependence on the O-D pair and the dynamic routing method in the interworking scenario of Figure 3

Dynamic routing method of originating exchange	D- to F-exchange	D- to D-exchange	F- to F-exchange and F- to D-exchange
EDR	EDR with unrestricted routing	EDR with unrestricted routing	Fixed routing
Hybrid SDR/EDR	Hybrid SDR/EDR with unrestricted routing	SDR with unrestricted routing	
SDR	SDR with routing restrictions, or fixed routing or TDR	SDR with unrestricted routing	
NOTE – The shaded field denotes interworking restrictions.			

7.3 Interworking of different dynamic routing methods

This subclause discusses the interworking of different dynamic routing methods. Those cases in which interworking can be improved by additional information exchange are identified. The situation for interworking different dynamic routing methods is similar to that of interworking dynamic routing methods with fixed routing and depends mainly on the dynamic routing method used at the originating exchange and on the compliance of the destination exchange to the information exchange requirements of the originating exchange, if any. Table 2 summarizes the results wherein it is assumed that there are no routing restrictions imposed by the VE or TE capabilities.

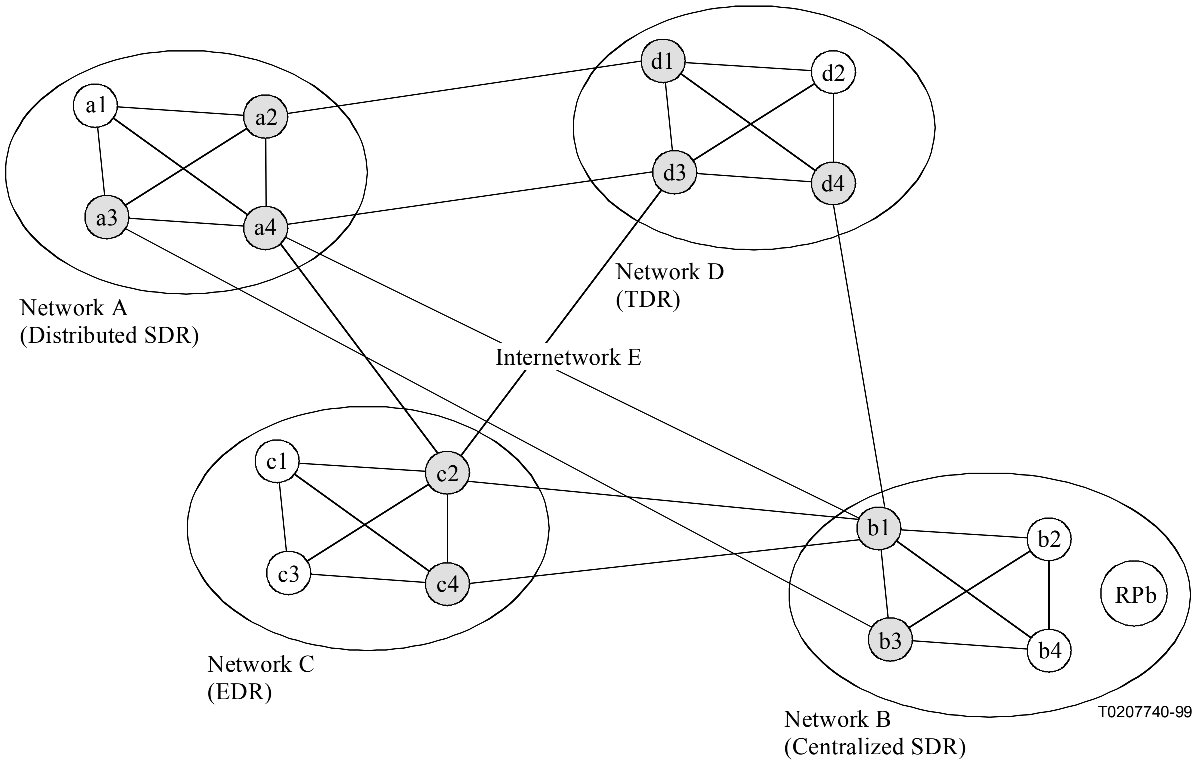
Table 2/E.350 – The routing at the originating exchange is dependent on the compliance of the destination exchange to the OE information exchange requirements, if any

Dynamic routing method of originating exchange	Destination exchange is	
	compliant to information exchange requirements of originating exchange	non-compliant to information exchange requirements of originating exchange
EDR	EDR with unrestricted routing	Not applicable
Hybrid SDR/EDR	SDR with unrestricted routing	Hybrid SDR/EDR with unrestricted routing
SDR	SDR with unrestricted routing	SDR with routing restrictions, or FR or TDR
NOTE – The shaded field denotes interworking restrictions.		

Routing restrictions result only for the case that the originating exchange has implemented an SDR method and the *destination* exchange does not comply with the originating exchange's information exchange requirements. Depending on the SDR penetration, this affects for example 25% of all O-D pairs if 50% of the exchanges use this SDR method and the other 50% are not compliant. For the other 75% of the O-D pairs, unrestricted dynamic routing is still possible. For those remaining O-D pairs with routing restrictions, interworking can be improved based on a bilateral agreement of the respective network operators to support additional specific information exchange.

7.4 Multiple step dynamic routing for calls traversing multiple networks

International and inter-operator calls may be routed dynamically in multiple networks. For example, as illustrated in Figure 5, consider four networks denoted as A, B, C, and D, where each network uses a different dynamic routing method. In this example, network A uses distributed call-by-call SDR, network B uses centralized periodic SDR, network C uses EDR, and network D uses TDR. Inter-operator network E, denoted here as internetwork E, is defined by the shaded exchanges in Figure 5 and is a virtual subnetwork where the interworking between networks A, B, C, and D is actually taking place.



NOTE – RPb denotes a routing processor in network B for a centralized periodic SDR method. The set of shaded exchanges defines an inter-operator network E for routing calls between networks A, B, C and D.

Figure 5/E.350 – Example of an internetworking scenario for dynamic routing

7.4.1 Internetwork E uses a Mixed Dynamic Routing (MXDR) method

Internetwork E can use various dynamic routing methods in delivering calls between the networks A, B, C, and D. For example, internetwork E can implement a mixed dynamic routing (MXDR) method in which each exchange in internetwork E uses the dynamic routing method used in its home network. Consider a call from exchange a1 in network A to exchange b4 in network B. Exchange a1 first routes the call to either exchange a3 or a4 in network A and in doing so uses distributed call-by-call SDR. In that regard exchange a1 first tries to route the call on the direct circuit group a1-a4, and assuming that all a1-a4 circuits are busy then sends a status query to exchange a4 and receives a status response back from exchange a4. Based on the status information, exchange a1 then selects a two-circuit-group route a1-a2-a4 and routes the call to exchange a4 via exchange a2. In so doing, exchange a1 and exchange a2 put the forward indicator in the call setup to identify the VEs and TE of the selected route for the call and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

Exchange a4 now proceeds to route the call to exchange b1 in network B using distributed call-by-call SDR. In that regard exchange a4 first tries to route the call on the direct circuit group a4-b1, and assuming that all a4-b1 circuits are busy then sends a status query to exchange b1 and receives a status response back from exchange b1. Based on the status information, exchange a4 then selects a two-circuit-group route a4-c2-b1 and routes the call to exchange b1 via exchange c2. In so doing, exchange a4 and exchange c2 put the forward indicator in the call setup to identify the selected route and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

If exchange c2 finds that circuit group c2-b1 is busy, it returns control of the call to exchange a4 through use of a crankback indicator when releasing the connection, as described in clause 8. If now exchange a4 finds that circuit group d4-b1 has idle capacity based on the status response from exchange b1, then exchange a4 could next try route a4-d3-d4-b1 to exchange b1. In that case exchange a4 routes the call to exchange d3 on circuit group a4-d3, and exchange d3 is sent a forward indicator in the call setup indicating the VEs and TE in the multilink route to exchange b1 via exchange d4, and whether circuit reservation should be applied or other exclusive routing decisions can be made, as discussed in clause 8. In that case exchange d3 tries to seize an idle circuit in circuit group d3-d4, and assuming that there is an idle circuit routes the call to exchange d4 with a forward indicator in the call setup indicating the VEs and TE is the multilink route to exchange b1, as described in clause 8. Exchange d4 then routes the call on circuit group d4-b1 to exchange b1, which has already been determined to have idle capacity. If on the other hand all d3-d4 circuits are busy, then exchange d3 returns control of the call to exchange a4 through use of a crankback indicator in the call release, as described in clause 8. At that point exchange a4 may try another multi-circuit-group route, such as a4-a3-b3-b1, using the same procedure for multi-circuit-group routing.

Exchange b1 now proceeds to route the call to exchange b4 in network B using centralized periodic SDR. In that regard exchange b1 first tries to route the call on the direct circuit group b1-b4, and assuming that all b1-b4 circuits are busy then selects a two-circuit-group route b1-b2-b4 which is the currently recommended alternate route from the routing processor (RPb) for network B. RPb bases its alternate routing recommendations on periodic (say every 10 seconds) circuit group and traffic status information received from each exchange in network B. Based on the status information, RPb then selects the two-circuit-group route b1-b2-b4 and sends this alternate route recommendation to exchange b1 on a periodic basis (say every 10 seconds). Exchange b1 then routes the call to exchange b4 via exchange b2. In so doing, exchange b1 and exchange b2 put the forward indicator in the call setup to identify the VEs and TE on the selected route and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

A call from exchange b4 in network B to exchange a1 in network A would mostly be the same as the call from a1 to b4, except with all the above steps in reverse order. The difference would be in routing the call from exchange b1 in network B to exchange a4 in network A.

Now consider a call from exchange c3 in network C to exchange d2 in network D. Exchange c3 first routes the call to exchange c2 in network C and in doing so uses EDR. In that regard exchange c3 first tries to route the call on the direct circuit group c3-c2, and assuming that all c3-c2 circuits are busy then selects the last successful two-circuit-group route c3-c1-c2 and routes the call to exchange c2 via exchange c1. In so doing, exchange c3 and exchange c1 put the forward indicator in the call setup to identify the VEs and TE of the selected route for the call and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

Exchange c2 now proceeds to route the call to exchange d3 in network D using EDR. In that regard exchange c2 first tries to route the call on the direct circuit group c2-d3, and assuming that all c2-d3 circuits are busy then selects the last successful two-circuit-group route c2-a4-d3 and routes the call to exchange d3 via exchange a4. In so doing, exchange c2 and exchange a4 put the forward indicator in the call setup to identify the VEs and TE in the selected route and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

If exchange a4 finds that circuit group a4-d3 is busy, it returns control of the call to exchange c2 through use of a crankback indicator when releasing the connection, as described in clause 8. Exchange c2 could next try route c2-b1-d4 to exchange d4. In that case exchange c2 routes the call to exchange d4 on circuit group c2-b1, and exchange b1 is sent a forward indicator in the call setup indicating the VEs and TE in the route to exchange d4 via exchange b1, and whether circuit reservation should be applied or other exclusive routing decisions can be made, as discussed in clause 8. If on the other hand all b1-d4 circuits are busy, then exchange b1 returns control of the call to exchange c2 through use of a crankback indicator in the call release, as described in clause 8. At that point exchange c2 may try a multi-circuit-group route, such as c2-a4-a2-d1, using the same procedure described above for multi-circuit-group routing. In that case exchange d1 now proceeds to route the call to exchange d2 in network D using TDR. In that regard exchange d1 first tries to route the call on the direct circuit group d1-d2, and assuming that all d1-d2 circuits are busy then selects a two-circuit-group route d1-d4-d2 which is the currently recommended alternate route in the TDR routing table. Exchange d1 then routes the call to exchange d2 via exchange d4. In so doing, exchange d1 and exchange d4 put the forward indicator in the call setup to identify the VEs and TE on the selected route and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

7.4.2 Internetwork E uses a single dynamic routing method

Internetwork E may also use a single dynamic routing method in delivering calls between the networks A, B, C and D. For example, internetwork E can implement a dynamic routing method in which each exchange in internetwork E uses EDR. In this case, the example call from exchange a1 in network A to exchange b4 in network B would only differ in the routing from exchange a4 to b1. In this case, exchange a4 proceeds to route the call to exchange b1 in network B using EDR. In that regard exchange a4 first tries to route the call on the direct circuit group a4-b1, and assuming that all a4-b1 circuits are busy then selects the current successful two-circuit-group route a4-c2-b1 and routes the call to exchange b1 via exchange c2. In so doing, exchange a4 and exchange c2 put the forward indicator in the call setup to identify the VEs and TE on the selected route and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8.

If exchange c2 finds that circuit group c2-b1 is busy, it returns control of the call to exchange a4 through use of a crankback indicator in releasing the connection, as described in clause 8. Exchange a4 could next try route a4-d3-d4-b1 to exchange b1. In that case exchange a4 routes the call to exchange d3 on circuit group a4-d3, and exchange d3 is sent a forward indicator in the setup indicating the VEs and TE in the multilink route and whether circuit reservation should be applied or other exclusive routing decisions can be made. In that case exchange d3 tries to seize an idle circuit in circuit group d3-d4, and assuming that there is an idle circuit routes the call to exchange d4 with a forward indicator in the setup indicating the VEs and TE in the selected route and whether circuit reservation should be applied or other exclusive routing decisions can be made, as described in clause 8. Exchange d4 then routes the call on circuit group d4-b1 to exchange b1 if that circuit group has idle capacity. If on the other hand all d3-d4 circuits are busy, then exchange d3 returns control of the call to exchange a4 through use of a crankback indicator in releasing the connection, as described in clause 8. At that point exchange a4 may try another multi-circuit-group route according to the particular EDR routing table rules in place, such as a4-a3-b3-b1, using the same procedure described above for multi-circuit-group routing.

A call from exchange b4 in network B to exchange a1 in network A would be the same as the call from a1 to b4, except with all the above steps in reverse order. In this case, the routing of the call from exchange b1 in network B to exchange a4 in network A would also use EDR in a similar manner to the a1 to b4 described above.

8 Information exchange needs

In this clause we discuss the information exchange required between network elements to implement the routing methods discussed in clauses 6 and 7. We discuss both call control information required for call setup and routing table design information required for routing table generation.

8.1 Call control information

Call control information is used to seize circuits in circuit groups, to release circuits in circuit groups, and for purposes of advancing route choices in the routing table. Existing call setup and release messages, as described in Recommendation Q.71, are used with additional indicators for call control functions. Actual selection of a route is determined from the routing table, and call control information is used to establish the route choice.

Forward indicators can denote the VEs and TE to be visited on a given route choice, and whether or not circuit reservation is to be applied on selection of a given circuit group. There can be a variable number of VEs specified in the forward indicator, from zero to a maximum number of 3 (tentative). Normally no alternate routing is allowed at a designated VE, only the designated route specified by the VEs and TE identified in the forward indicator can be used and alternate routes within the non-hierarchical network are not allowed at a VE. The forward indicator can specify that circuit reservation is to be used or not to be used. Furthermore, if circuit reservation is used, the forward indicator specifies either the number of circuits or percentage of circuits in the circuit group to be reserved for direct traffic. In addition, circuit reservation as defined in Recommendation E.412 can be specified to be used. The forward indicator also denotes to the succeeding VEs the possibility of making an exclusive decision, based on information sent in the forward indicator(s), as to whether or not alternate routing is allowed, conditionally or unconditionally.

Backward indicators in a connection release are used to return control to a previous VE or to the OE for possible further alternate routing. For example, a backward indicator, or crankback, is used in the automatic rerouting function described in Recommendation E.170.

In Annex B we give specific examples of the use of forward indicators and backward indicators based on various implemented dynamic routing methods described in Annex A. These examples help clarify the particular functionality associated with these forward and backward indicators.

8.2 Routing table design information

Routing table design information is used for purposes of applying the routing table design rules for determining route choices in the routing table. This information is exchanged between one switch and another switch, such as between the OE and DE, for example, or between a switch and a network element such as a routing processor (RP). This information is used to generate the routing table, and then the routing table is used to determine the route choices used in the selection of a route. Then the call control information is used to establish the route choice.

Exchange of routing table design information allows one network operator to query for state information or other parameters, which can include, for example, circuit group status, traffic performance information, quality information, cost information, or allowed traffic volume information, of another network operator's network. The information exchange items can include those specified in Recommendation E.411, which for example may identify occupancy, total attempts, overflow attempts, available circuits, and other items.

In Annex B we give specific examples of the use of the exchange of routing table design information, based on various implemented dynamic routing methods described in Annex A. These examples help clarify the particular functionality associated with these exchanges of routing table design information.

ANNEX A

Dynamic routing functional models

In this annex we give examples of the TDR, SDR and EDR methods discussed in 6.2, 6.3, and 6.4. We present eight dynamic routing functional models, as follows:

1) Figure A.1 – Dynamic Non-hierarchical Routing (DNHR).
2) Figure A.2 – Dynamically Controlled Routing (DCR).
3) Figure A.3 – Worldwide Intelligent Network (WIN) Dynamic Routing.
4) Figure A.4 – Real-Time Network Routing (RTNR).
5) Figure A.5 – Dynamic Alternate Routing (DAR).
6) Figure A.6 – State-and-Time Dependent Routing (STR).
7) Figure A.7 – Distributed Adaptive Dynamic Routing (DADR).
8) Figure A.8 – Optimized Dynamic Routing (ODR).

It should be noted that these are illustrative examples of proprietary routing methods, many of which are protected by intellectual property. This list of routing methods is illustrative of the methods outlined in 6.2, 6.3 and 6.4, but their inclusion in Annex A should not be construed as a recommendation of these specific methods in any way.

A.1 Dynamic Non-hierarchical Routing (DNHR) functional model

Figure A.1 illustrates a functional model of dynamic non-hierarchical routing (DNHR). This functional description illustrates routing functions in each circle, and the flow of information between functions on the lines connecting the circles.

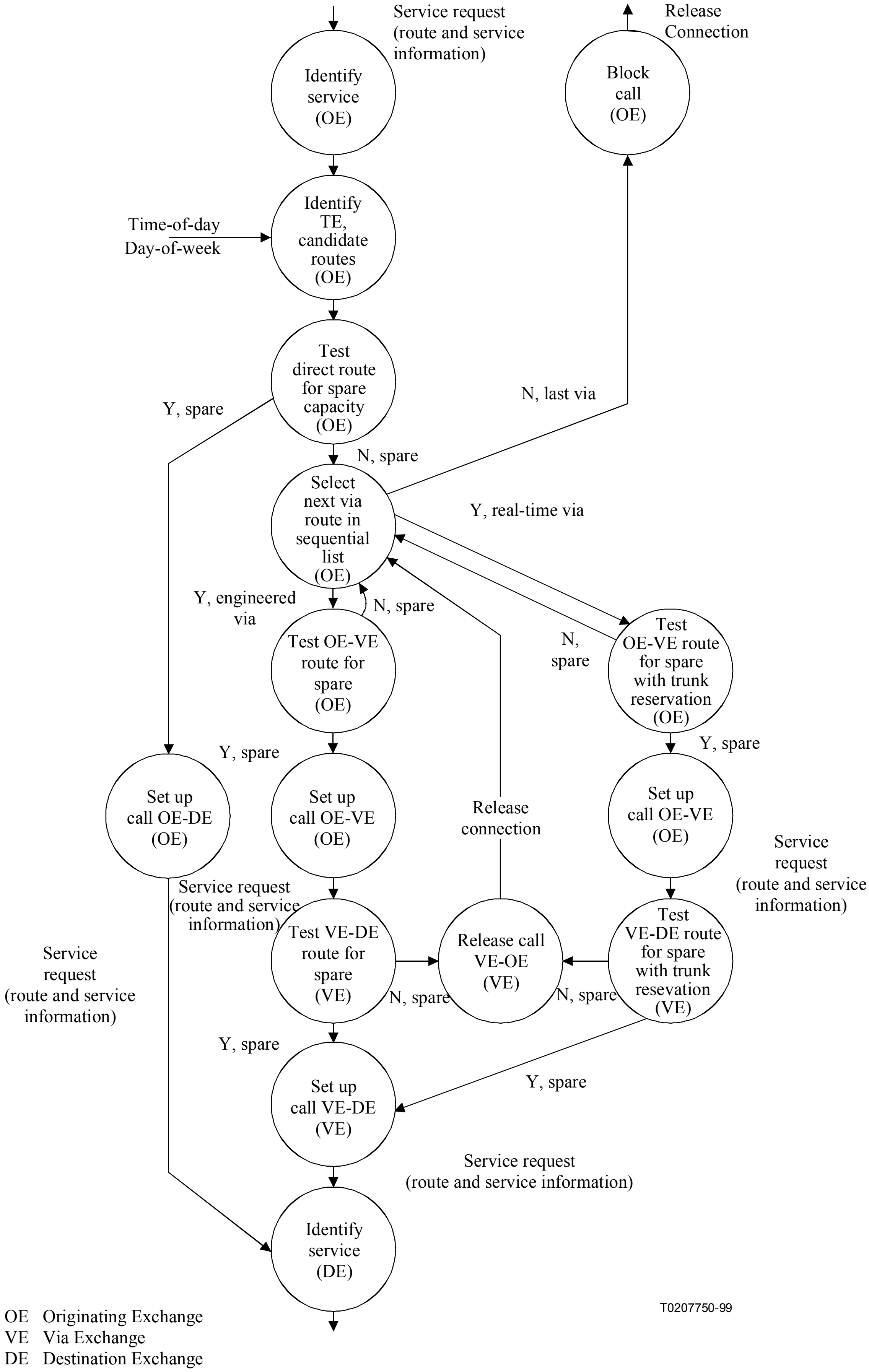


Figure A.1/E.350 – DNHR functional model

In Figure A.1, the circle at the top indicates that a first step is for the switch to identify the DE and routing table information to the DE. The OE then tests for spare capacity on the direct route, if it exists, and if there is spare capacity sets up the call to the DE (left branch of logic flow). The OE makes a service request to the DE in which it supplies the DE with the needed service information and route information to complete the call. The OE then may first try the direct circuit group between the OE and DE, and if blocked overflows to the next OE-VE-DE route in the route set as determined by the routing table rules. The DNHR route sets are preplanned, loaded, and stored in each OE. In Figure A.1 it is assumed that the DNHR alternate route set consists of two-circuit-group routes which are hunted sequentially. In the functional model there are a set of two-circuit-group alternate routes called "engineered routes", which are hunted for an idle circuit without the use of CR restrictions. The engineered routes are followed in the route sequence by a set of two-circuit-group alternate routes called "real-time routes", in which CR restrictions are applied.

In Figure A.1, if the current alternate route is a two-circuit-group engineered route, for example, the OE-VE circuit group is tested for an idle circuit without CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the VE. The forward indicator in the setup message instructs the VE to route the call directly to the DE, without CR restrictions, and not perform any further alternate routing. The VE then tests the VE-DE circuit group for an idle circuit, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE route and to perform terminating routing functions. If the call overflows the second circuit group (VE-DE) of the OE-VE-DE route, the call is returned to the OE for possible further alternate routing to the next route in the sequence. Control is returned by sending a release message with a crankback indicator from the VE to OE. The crankback indicator instructs the OE to continue to route the call on additional alternate routes in the sequence, or if there are none to block the call. For multiple-circuit-group routes in the route set, the forward indicator in the setup message indicates all VEs included in the route, and the crankback indicator in the release message may return the call to a previous VE or to the OE.

For real-time route selection subject to CR restrictions, as illustrated in the right branch of Figure A.1, CR is applied to each circuit group in the route. For example, for a two-circuit-group OE-VE-DE route, the OE-VE circuit group is tested for an idle circuit subject to the CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the VE. In this case, the forward indicator in the setup message instructs the VE to route the call directly to the DE, to not perform any further alternate routing, and to apply the CR restrictions in seizing an idle circuit on the VE-DE circuit group. The VE then tests the VE-DE circuit group for an idle circuit subject to the CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE real-time route and to perform terminating routing functions. If the call overflows the second circuit group (VE-DE) of the OE-VE-DE route, the call is returned to the OE for possible further alternate routing to the next real-time route in the sequence. Control is returned by sending a release message with a crankback indicator from the VE to OE. The crankback indicator instructs the OE to continue to route the call on additional alternate routes in the sequence, or if there are none to block the call.

A.2 Dynamically Controlled Routing (DCR) functional model

Figure A.2 illustrates a functional model of dynamically controlled routing (DCR), which is an example of centralized periodic SDR. Here the centralized RP obtains circuit group status and traffic status information from the various exchanges on a periodic basis, that is every 10-15 seconds, and performs a computation of the optimal routing table on a periodic basis every 10-15 seconds. To determine the optimal routing table, the RP executes the DCR routing table optimized on procedure, which is a particular implementation of LLR, and transmits the routing tables to the network exchanges on a periodic basis every 10-15 seconds.

Figure A.2 illustrates DCR routing functions in each circle, and the flow of information between functions on the lines connecting the circles.

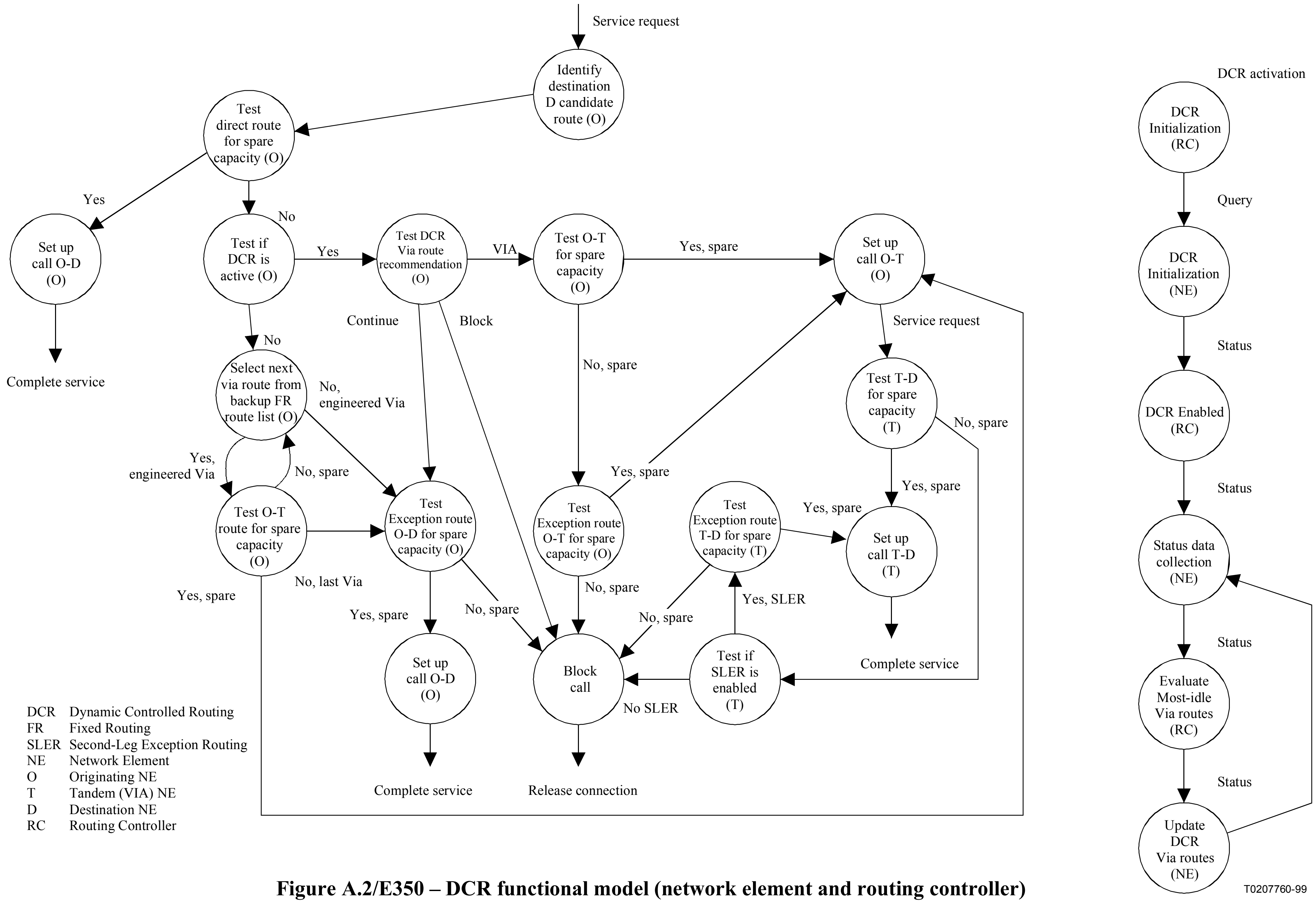


Figure A.2/E350 – DCR functional model (network element and routing controller)

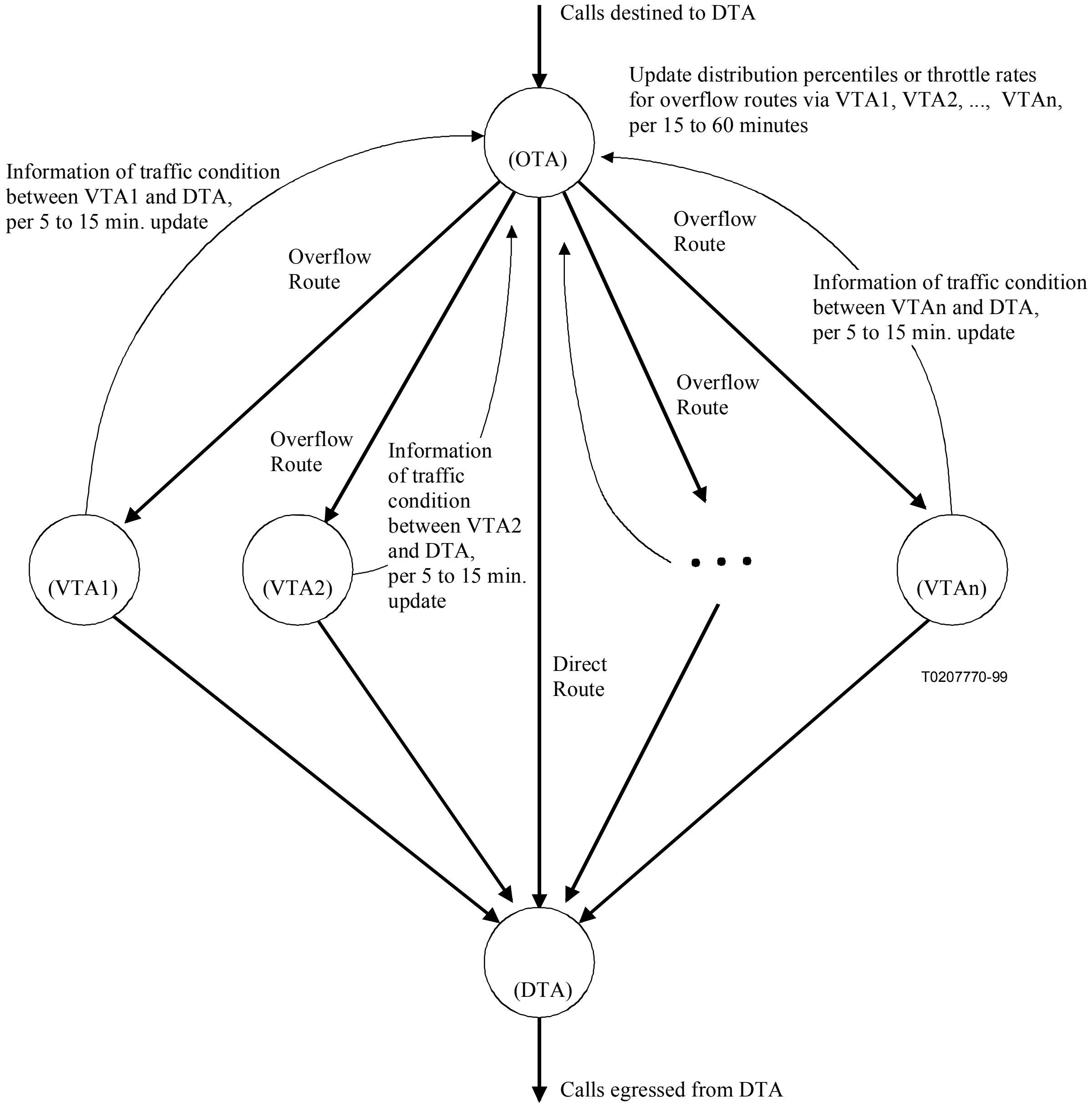
In Figure A.2 the circle at the top indicates that a first step is for the switch to identify the DE and routing table information to the DE. The OE then tests for spare capacity on the direct route, if it exists, and if there is spare capacity sets up the call to the DE. The OE makes a service request to the DE in which it supplies the DE with the needed service information and route information to complete the call. The OE then may first try the direct circuit group between the OE and DE, and if blocked overflows to the next OE-VE-DE route in the routing table, as determined by the routing table rules. In the example in Figure A.2, it is assumed that the SDR alternate route consists of the two-circuit-group route recommended by the RP. TR, or "circuit protection" restrictions, are applied by the RP in the selection of these two-circuit-group via routes.

In Figure A.2, if the current alternate route is the two-circuit-group via route recommended by the RP, the OE-VE circuit group is tested for an idle circuit without CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the VE. The forward indicator in the setup message instructs the VE to route the call directly to the DE, without CR restrictions, and not perform any further alternate routing. The VE then tests the VE-DE circuit group for an idle circuit, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE route and to perform terminating routing functions. If the call overflows the second circuit group (VE-DE) of the OE-VE-DE route, the call is returned to the OE for possible further alternate routing to the next route in the sequence. Control is returned by sending a release message with a crankback indicator from the VE-to-OE. The crankback indicator instructs the OE to continue to route the call on additional alternate routes in the sequence, or if there are none to block the call.

A.3 Worldwide Intelligent Network (WIN) dynamic routing functional model

Figure A.3 illustrates a functional model of worldwide intelligent network (WIN) dynamic routing, which is an example of distributed periodic SDR. Here each exchange in the WIN dynamic routing network obtains circuit group status and traffic status information from the other exchanges on a periodic basis, that is, every five minutes. Each exchange uses the status information to perform a computation of the optimal routing table every five minutes, in which the routing table design rules use a particular implementation of LLR.

Figure A.3 illustrates WIN dynamic routing functions in each circle, and the flow of information between functions on the lines connecting the circles.



OTA Originating Telecommunications Administration
DTA Destination Telecommunications Administration
VTA VIA Telecommunications Administration

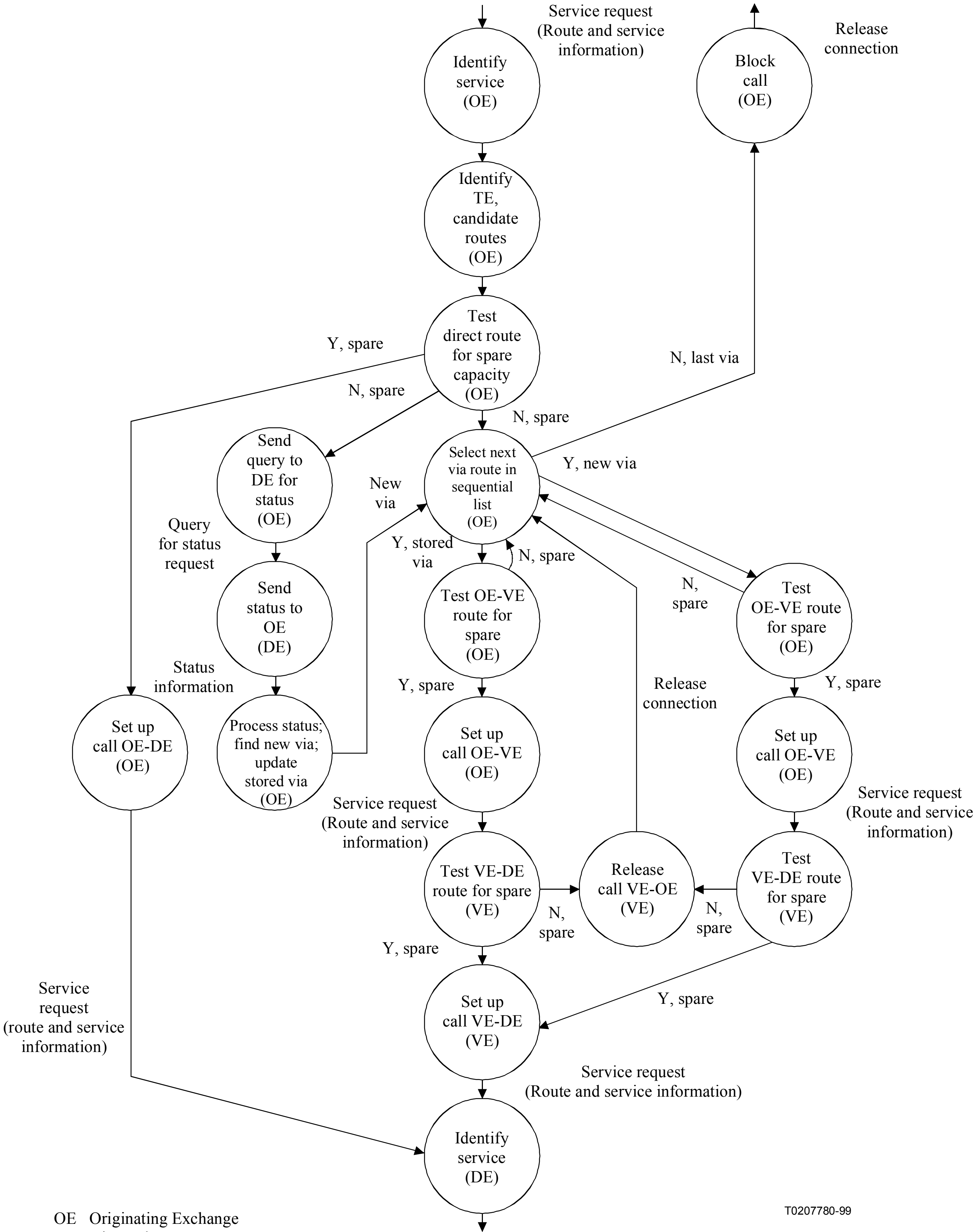
Figure A.3/E.350 – WIN Functional Model

In Figure A.3 the circle at the top indicates that a first step is for the switch to identify the DE and routing table information to the DE. The OE then tests for spare capacity on the direct route, if it exists, and if there is spare capacity sets up the call to the DE. The OE makes a service request to the DE in which it supplies the DE with the needed service information and route information to complete the call. The OE then may first try the direct circuit group between the OE and DE, and if blocked overflows to the next OE-VE-DE route in the routing table, as determined by the routing table rules. In the example in Figure A.2, it is assumed that the SDR alternate route consists of the two-circuit-group route determined by the OE based on the status information received from the other exchanges in the WIN dynamic routing network. CR restrictions are applied in the selection of these two-circuit-group via routes.

In Figure A.3, if the current alternate route is the two-circuit-group via route determined by the OE based on the status information, the OE-VE circuit group is tested for an idle circuit with CR restrictions. If available, a circuit is seized and a setup message with a forward indicator is sent to the VE. The forward indicator in the setup message instructs the VE to route the call directly to the DE, with CR restrictions, and not perform any further alternate routing. The VE then tests the VE-DE circuit group for an idle circuit, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE route and to perform terminating routing functions. If the call overflows the second circuit group (VE-DE) of the OE-VE-DE route, the call is returned to the OE for possible further alternate routing to the next route in the sequence. Control is returned by sending a release message with a crankback indicator from the VE to OE. The crankback indicator instructs the OE to continue to route the call on additional alternate routes in the sequence, or if there are none to block the call.

A.4 Real-Time Network Routing (RTNR) functional model

Figure A.4 illustrates an example functional model of real-time network routing (RTNR). This functional description illustrates routing functions in each circle, and the flow of information between functions on the lines connecting the circles.



OE Originating Exchange
VE Via Exchange
DE Destination Exchange

Figure A.4/E.350 – RTNR functional model

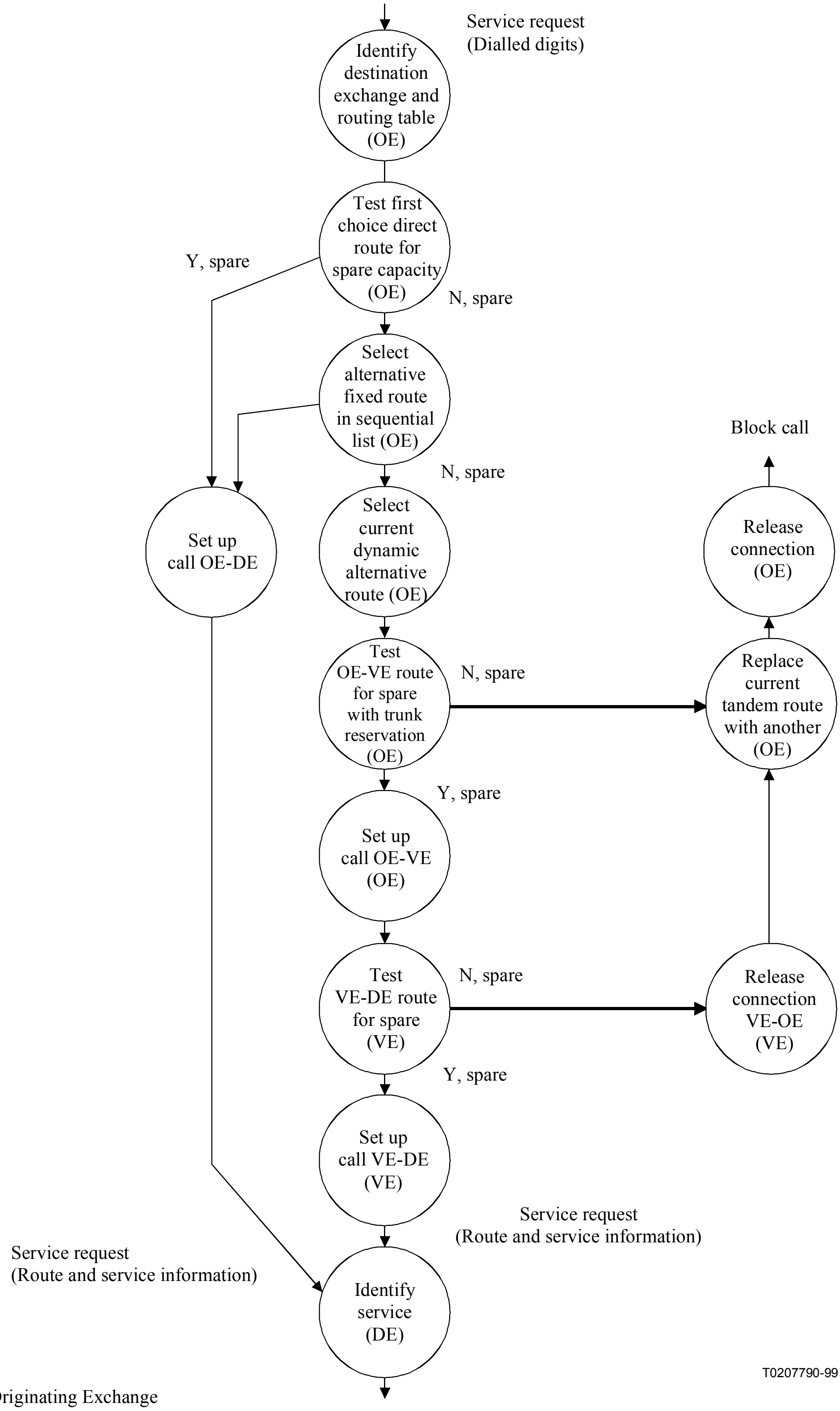
In Figure A.4, the circle at the top indicates that a first step is for the switch to identify the DE and routing table information to the DE. The OE then tests for spare capacity on the direct route, if it exists, and if there is spare capacity sets up the call to the DE (left branch of logic flow in Figure A.4). The OE makes a service request to the DE in which it supplies the DE with the needed service information and route information to complete the call. The OE then may first try the direct circuit group between the OE and DE, and if blocked overflows to the next OE-VE-DE route in the routing table, as determined by the routing table rules. In Figure A.4 the RTNR alternate route consists of two-circuit-group routes which are hunted sequentially. In the example the first alternate route selection is a two-circuit-group alternate route called the "stored via", which is the alternate route determined by exchange of status information between the DE and OE on the previous OE-DE call. If this stored via route is blocked on either the OE-VE or VE-DE circuit group, the next alternate route tried is the two-circuit-group via route determined by exchange of status information between the DE and OE on the current OE-DE call. CR restrictions are applied as needed in the selection of these two-circuit-group via routes.

In Figure A.4, if the current alternate route is a two-circuit-group stored via route, for example, the OE-VE circuit group is tested for an idle circuit without CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the VE. The forward indicator in the setup message instructs the VE to route the call directly to the DE, without CR restrictions, and not perform any further alternate routing. The VE then tests the VE-DE circuit group for an idle circuit, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE route and to perform terminating routing functions. If the call overflows the second circuit group (VE-DE) of the OE-VE-DE route, the call is returned to the OE for possible further alternate routing to the next route in the sequence. Control is returned by sending a release message with a crankback indicator from the VE to OE. The crankback indicator instructs the OE to continue to route the call on additional alternate routes in the sequence, or if there are none to block the call. For multiple-circuit-group routes in the route set, the forward indicator in the setup message indicates all VEs included in the route, and the crankback indicator in the release message may return the call to a previous VE or to the OE.

In parallel with setting up a call on the stored via route, the OE sends a status query request to the DE to determine the VE-DE circuit group status, as shown in the second from the left branch in Figure A.4. The OE processes the status response to determine the new via alternate route choice. This new via alternate route becomes the stored via route for the next call, if the current stored via route is successful. Otherwise, the new via alternate route is used to set up the current call. Setting up the call on the new via alternate route is illustrated on the right branch of Figure A.4, and follows the same steps used in setting up the call on the current stored via route.

A.5 Dynamic Alternate Routing (DAR) functional model

Figure A.5 illustrates a functional model of dynamic alternate routing (DAR). This functional description illustrates routing functions in each circle, and the flow of information between functions on the lines connecting the circles.



OE Originating Exchange
VE Via Exchange
DE Destination Exchange

Figure A.5/E.350 – DAR functional model

In Figure A.5 the circle at the top indicates that a first step is for the switch to identify the DE and routing table information to the DE. The OE then tests for spare capacity on the direct route, if it exists, and if there is spare capacity sets up the call to the DE (left branch of logic flow). The OE makes a service request to the DE in which it supplies the DE with the needed service information and route information to complete the call and if blocked overflows to the next OE-VE-DE route in the route set as determined by the routing table rules. In Figure A.5 the DAR alternate route consists of the dynamic alternative two-circuit-group route. This dynamic alternative via route is the one that was last successfully used as an alternate route for the previous OE-DE call.

The dynamic alternate route selection is subject to CR restrictions, and CR is applied to each circuit group in the route. For example, as illustrated in Figure A.5, for the two-circuit-group OE-VE-DE route, the OE-VE circuit group is tested for an idle circuit subject to the CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the VE. In this case, the forward indicator in the setup message instructs the VE to route the call directly to the DE and to not perform any further alternate routing. The VE then tests the VE-DE circuit group for an idle circuit subject to the CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE real-time route and to perform terminating routing functions.

If the call overflows the first circuit group (OE-VE) or the second circuit group (VE-DE) of the OE-VE-DE route, the call is released back to the OE, and no further alternate routing is applied by the OE. In that case, as illustrated in the right branch of Figure A.5, the OE selects a new dynamic alternate route by applying the routing table design rules.

A.6 State- and Time-Dependent Routing (STR) functional model

Figure A.6 illustrates a functional model of state- and time-dependent routing (STR). This functional model illustrates routing functions in each circle, and the flow of information between functions on the lines connecting the circles.

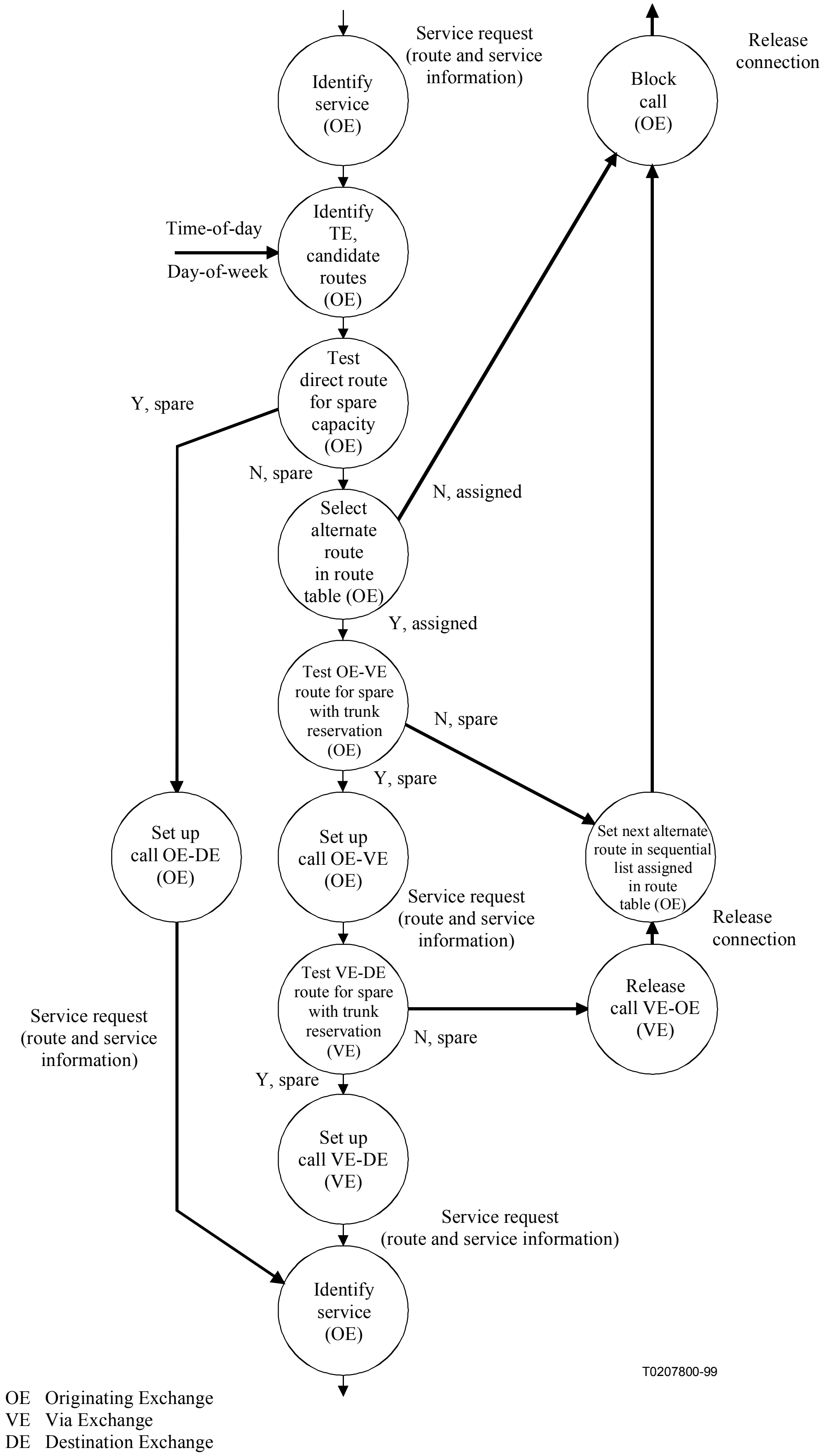


Figure A.6/E.350 – STR functional model

In Figure A.6, the circle at the top indicates that a first step is for the switch to identify the DE and routing table information to the DE. The OE then tests for spare capacity on the direct route, if it exists, and if there is spare capacity sets up the call to the DE (left branch of logic flow). The OE makes a service request to the DE in which it supplies the DE with the needed service information and route information to complete the call. The OE then may first try the direct circuit group between the OE and DE, and if blocked overflows to the next OE-VE-DE route in the route set as determined by the routing table rules. In Figure A.6 the STR alternate route consists of the dynamic alternative two-circuit-group route. This dynamic alternative via route is the one that was last successfully used as an alternate route for the previous OE-DE call. In STR, the set of candidate via routes is changed as a function of time to reflect the effects of non-coincidence of traffic in the STR network.

The dynamic alternate route selection is subject to CR restrictions, and CR is applied to each circuit group in the route. For example, as illustrated in Figure A.6, for the two-circuit-group OE-VE-DE route, the OE-VE circuit group is tested for an idle circuit subject to the CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the VE. In this case, the forward indicator in the setup message instructs the VE to route the call directly to the DE, to not perform any further alternate routing, and to apply the CR restrictions in seizing an idle circuit on the VE-DE circuit group. The VE then tests the VE-DE circuit group for an idle circuit subject to the CR restrictions, and if available a circuit is seized and a setup message with a forward indicator is sent to the DE. The forward indicator in the setup message instructs the DE that the call is terminating on a OE-VE-DE real-time route and to perform terminating routing functions.

If the call overflows the first circuit group (OE-VE) or the second circuit group (VE-DE) of the OE-VE-DE route, the call is released back to the OE, and no further alternate routing is applied by the OE. In that case, as illustrated in the right branch of Figure A.6, the OE selects a new dynamic alternate route by applying the routing table design rules.

A.7 Distributed Adaptive Dynamic Routing (DADR) functional model

Figures A.7a and A.7b illustrate a functional model of distributed adaptive dynamic routing (DADR). This functional model illustrates routing functions in each circle, and the flow of information between functions on the lines connecting the circles.

A.7.1 General information about DADR

DADR has the capability to trace and utilize network resources without interfering with direct routed traffic, either by selection of alternative routes in a predefined sequential order or by learning. The control is based on real-time downstream observations which are utilized to trace spare network capacity, save processor load, and avoid network overload. Alternative routing methods used in EDR and ARR are adapted to direct routing in order to find usable routes, and, combined with circuit reservation (according to Recommendation E.412), to utilize idle network resources.

For each adapted network, a backward indicator(s) is sent in the release message to inform the preceding switch about network congestion. A forward indicator(s) in the setup message guarantees that only one rerouting attempt is made in each alternative routing situation (dynamic routing program). The forward indicator(s) is generated when a call has been rerouted, and follows the call to the destination. This forward indicator(s) informs the downstream network to take direct routes to the destination. However, each network has the possibility to make an exclusive decision upon receiving the sent forward information as well as backward information. The flexibility of DADR makes it possible to interwork with other routing and traffic management functions (Recommendations E.170, E.412).

A.7.2 Description of the DADR functional model (Figure A.7)

Basically DADR operates as follows: A call is usually offered to a direct route to the DE from the fixed routing program. If a direct route to the DE is found, a call setup from the OE to the DE is initiated and the OE supplies the DE with the necessary service and route information to complete the call (left branch in Figure A.7a).

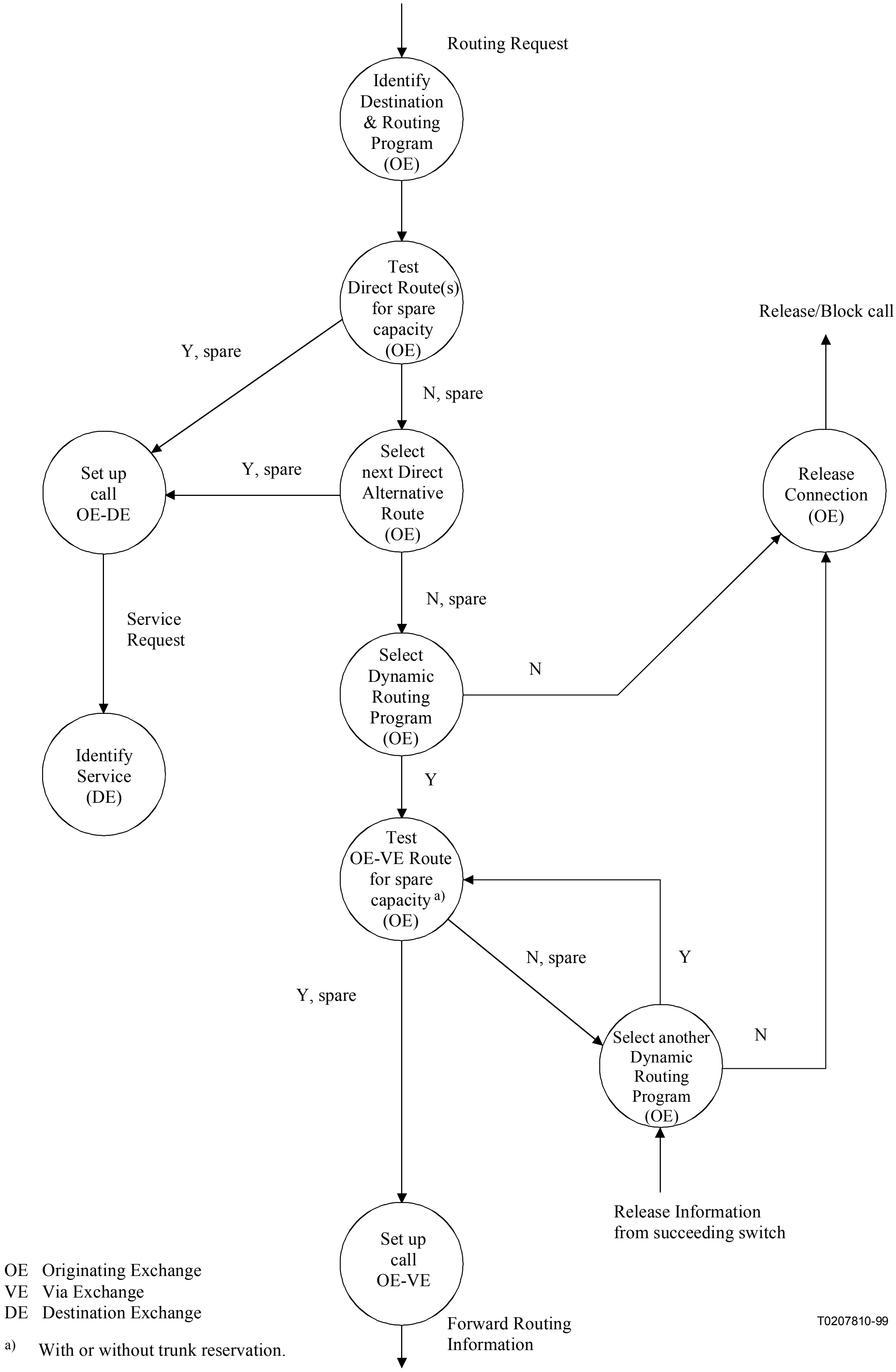
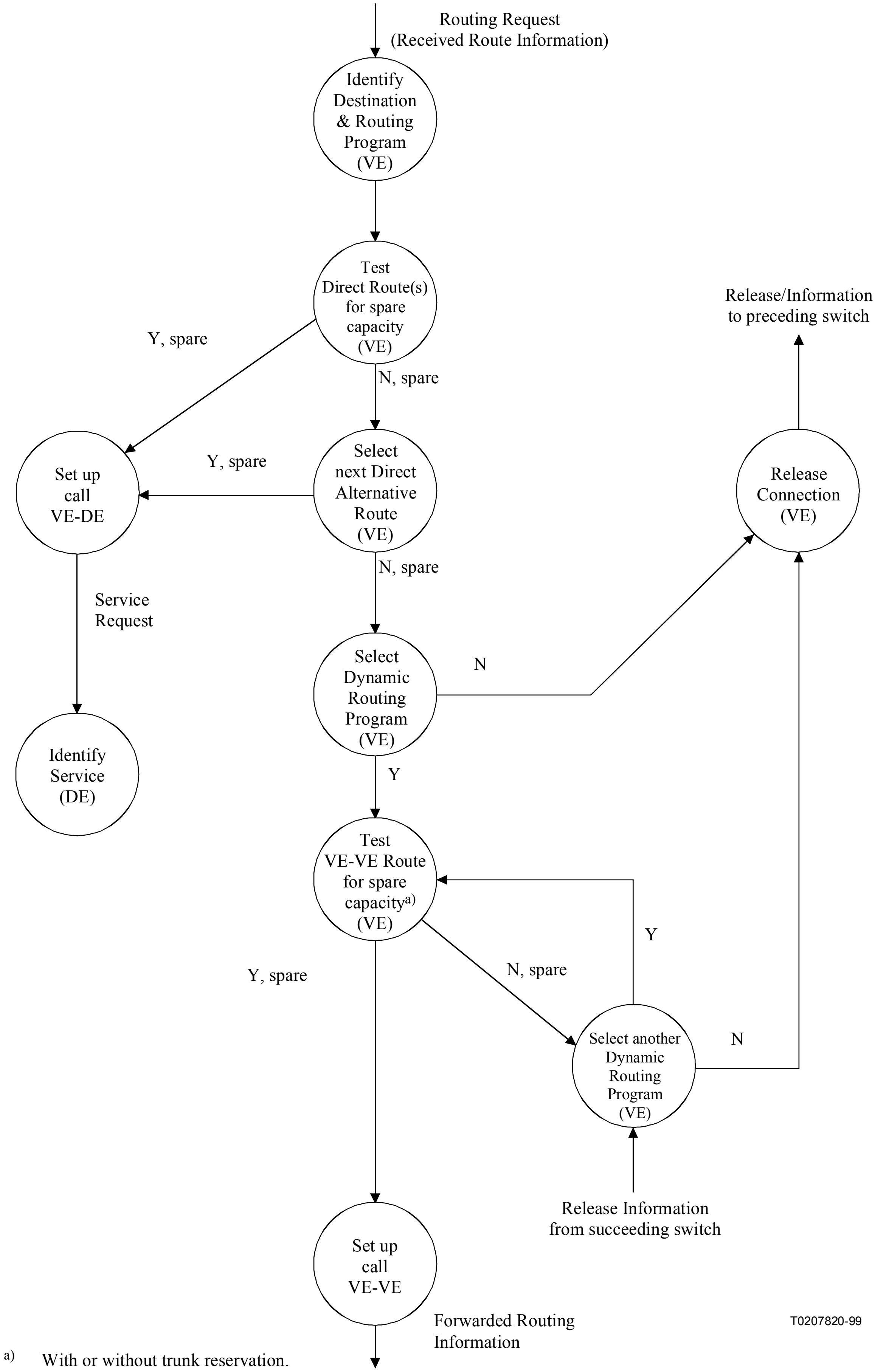


Figure A.7a/E.350 – DADR functional model



a) With or without trunk reservation.

Figure A.7b/E.350 – DADR functional model

In case no direct routes from the fixed routing program are available, the OE selects a dynamic routing program (EDR or ARR based), and tests for spare capacity. In case no available route is found to the VE in the selected dynamic routing program, the OE may select a second dynamic routing program (if specified). If this also results in no free route to the VE, the call will be released/blocked (right branch in Figure A.7a). If the OE is able to find a free route in one of the dynamic routing programs, a call set-up (OE-VE) is initiated. The OE supplies the VE with information (forward indicators) about which dynamic routing programs were previously used in the call set-up.

The VE then tests for spare capacity in the fixed routing program. If a direct route to the DE is found, a call set-up VE-DE is initiated and the VE supplies the DE with the necessary service- and route information to complete the call (left branch in Figure A.7b). In case no free direct route is found, the VE then selects a dynamic routing program. Selection of the dynamic routing program is dependent on the received forward indicators. If the received information indicates that for example the dynamic routing program has already used ARR in the previous switch (OE), DADR will not allow the VE to use a dynamic routing program based on ARR, but may use a dynamic routing program based on EDR. If the received information indicates that both dynamic routing programs were used in the previous switch (OE), then the VE will not allow the use of any dynamic routing programs, and the call attempt in the VE will be refused and the release information sent to the preceding switch. If a free route is found by one of the dynamic routing programs, a call set-up VE-VE is initiated. The VE will supply the subsequent VE with information (forward indicators) about which dynamic routing programs were previously used in the call set-up. The call set-up procedure with respect to routing for the subsequent VE(s) is according to the above description.

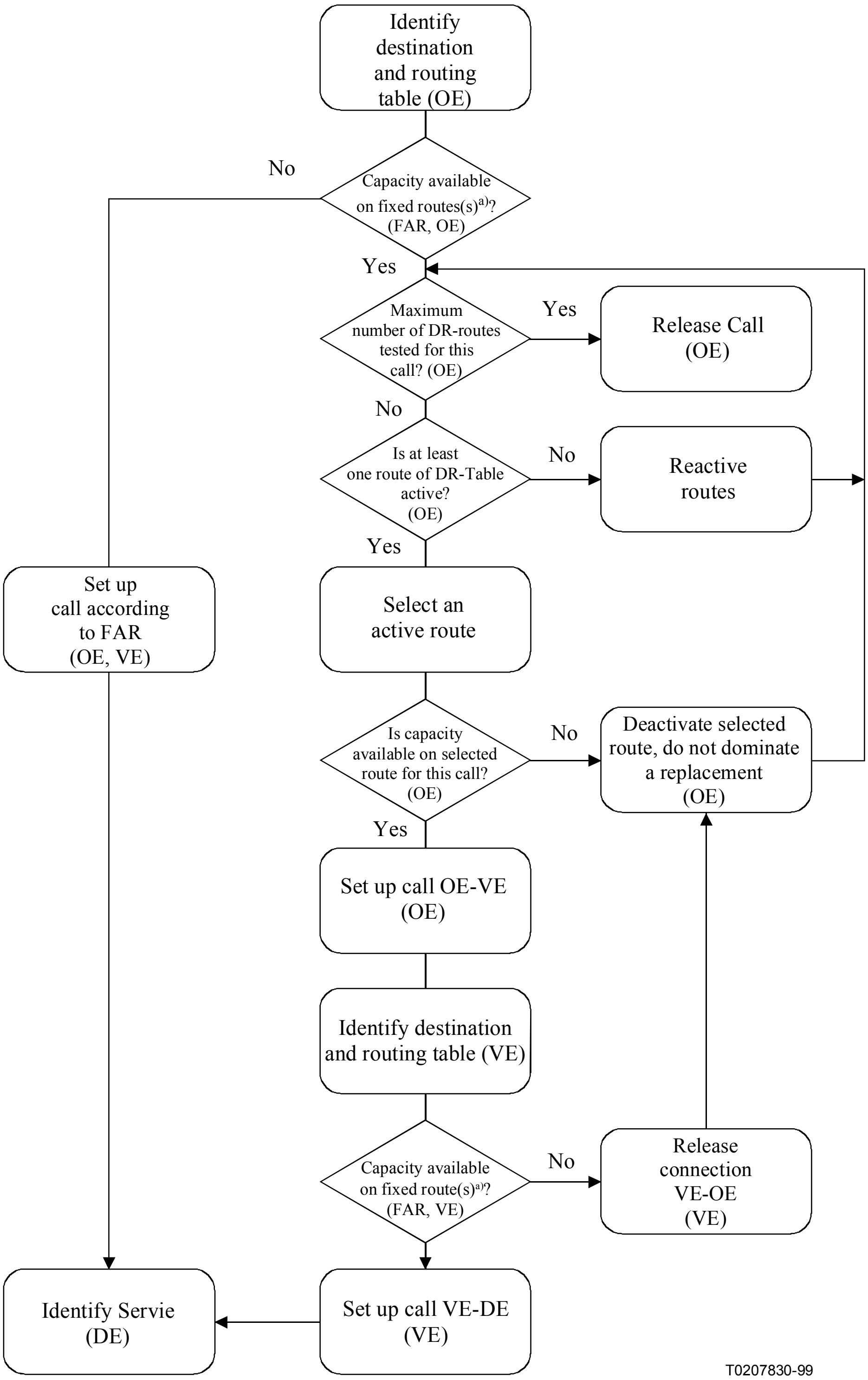
In case an ongoing call set-up is blocked due to congestion in the network, for example the VE is unable to find a free route towards the destination (DE, or VE-DE), information indicating the cause of congestion (EDR or ARR based congestion) is returned to instruct the previous switch (OE or VE) about further re-routing. If ARR already was used previously during the call set-up (as indicated in the forward indication), and the cause of congestion also indicates ARR, the dynamic routing program using ARR cannot be used further. If EDR has not been used previously, then an attempt to use a dynamic routing program based on EDR may be tried. If EDR also was used previously, the call connection will be released and the call blocked since there is very little chance for a successful call connection.

A.8 Optimized Dynamic Routing (ODR) Functional Model

Figure A.8 illustrates a functional model of optimized dynamic routing (ODR). This functional description illustrates routing functions in each circle, and the flow of information between functions on the lines connecting the circles. Variations to this model are possible because of flexible interworking with other existing routing (e.g. E.170) and traffic management function (e.g. E.412).

ODR is a decentralized, event-dependent dynamic routing method. Basically ODR operates as follows. A call is usually first offered by the OE to one or more fixed routes using fixed alternate routing (left branch in Figure A.8). In many cases this fixed routing list will contain only the direct route to the DE. If the routes in the fixed routing list are not available for the call, the call is offered to an alternate dynamic route (DR-route) which is selected from a set of active DR-routes. The selected DR-route is either the last one successfully used, or a new one in the case the last one was already used a number of times in succession. If the selected alternate DR-routes turns out to be not available for this call (either on the first or on the second selection), this route is temporarily deactivated (lower right side branch in Figure A.8) and a new active route is selected for the call. For a deactivated DR-route *no* replacement route is nominated. Therefore the set of active DR-routes reduces in size and adapts to those alternate routes being highly available in a respective busy hour. If the set of active DR-routes becomes empty, deactivated DR-routes are re-activated again by call processing.

A call is offered only to a limited number of DR-routes. If this number is exceeded, the call is released by the OE. If a call is released due to congestion by the VE , the call may optionally be rerouted via another alternate route following E.170. Traffic management controls (e.g. circuit reservation) as described in Recommendation E.412 can be applied in each exchange. For this purpose the different types of traffic streams of the dynamic routing network can be identified. ODR does not require any specific information exchange.



OE Origination Exchange
VE Via Exchange
DE Destination Exchange
DR Dynamic Routing
FAR Fixed Alternate Routing

a) Usually a direct route.

NOTE – Many variations of this model are possible because of flexible interworking capabilities with other existing routing and traffic management features (e.g. circuit reservations).

Figure A.8/E.350 – ODR functional model

ANNEX B

Information exchange examples

In this annex, we illustrate examples of the information exchange between network elements to implement the routing methods discussed in clauses 6 and 7. We illustrate both call control information required for call setup and routing table design information required for routing table generation. We give specific examples of the use of forward indicators, backward indicators, and routing table design information exchange based on various implemented dynamic routing methods described in Annex A. These examples help clarify the particular functionality associated with the forward and backward indicators and routing table design information exchange.

B.1 Examples of call control information

Forward information exchange is used in call setup, and includes for example initial address messages used in Common Channel Signalling (CCS) and other types of forward information exchange. The following are examples of additional parameters used in the SETUP message for particular implementations of dynamic routing methods described in Annex A:

1) SETUP-VDL: the via and destination exchange list (VDL) in SETUP message specifies all via exchanges (VEs) and the destination exchange (DE), such as used in DNHR, STR, and RTNR described in Annex A.
2) SETUP-RES: the reservation (RES) parameter in SETUP message specifies the level of circuit reservation (if any) applied at via exchanges (VEs), such as used in DNHR, DADR, DCR, STR and RTNR as described in Annex A.

Backward information exchange is used to release a call on a circuit in a circuit group such as from as DE to a VE or from a VE to an OE and include for example release messages in CCS and other types of backward information flow. The following is an example of an additional crankback parameter used in the RELEASE message for particular implementations of dynamic routing methods described in Annex A:

– RELEASE-CB: the crankback (CB) parameter in RELEASE message sent from VE or TE to OE to allow further alternate routing at OE, such as used in DNHR, DADR, DCR and RTNR as described in Annex A.

B.2 Examples of routing table design information

Routing table design information exchange is used for example by an OE to send a query for status request to a DE, by an OE/VE/DE to send status information to an RP informing the RP of the circuit group status, by a DE to send status information to OE, or by an RP to send a routing recommendation to an OE/VE/DE. The following are examples of information exchange items for routing table design for particular implementations of dynamic routing methods described in Annex A.

1) QUERY: provides OE-to-DE or OE-to-RP (depending on implementation) request for circuit group status.
2) STATUS: provides OE/VE/DE-to-RP or DE-to-OE (depending on implementation) information reporting circuit group status.
3) RECOM: provides RP-to-OE/VE/DE information giving a routing recommendation.

B.3 Examples of information exchange

In this subclause we illustrate the use of information exchange in setting up a call for the routing methods discussed in clauses 6 and 7. Here we give examples of the use of the forward and backward information exchange used for call control and routing table design purposes, in which the examples are based on particular implementations of dynamic routing methods described in Annex A. We also define the generic routing functions taken in association with the information flows.

B.3.1 Examples of call control information exchange

Figure B.1 illustrates five call control information flow examples. The first example marked as ① indicates that the OE sends the DE the SETUP-VDL/RES information (which identifies the OE and DE), if it is setting up a call on the direct route. In this case the OE accesses the routing table and finds that the direct route is the current choice. The DE receives the SETUP-VDL/RES information flow, and then knows that it should provide destination routing treatment for the call. Destination routing treatment could mean routing the call to an exchange within the served area of the DE, or between the DE and a gateway exchange in another network. In particular, the SETUP-VDL/RES information at the DE instructs the DE not to further route the call within the present dynamic routing network, so that circular routing is therefore prohibited.

In the second information flow example marked as ②, the OE accesses the routing table and finds that the via route through VE to DE is the current choice. The OE then sends the SETUP-VDL/RES information (which identifies the OE, VE, DE, and no-circuit-reservation) from the OE to the VE and then from the VE to the DE in order to set up a two-circuit-group connection from the OE through the VE to the DE, without the use of circuit reservation. The VE receives the SETUP-VDL/RES information flow and knows to then access the circuit group from the VE to the DE. If there is an available circuit, as illustrated in example ② in Figure B.1, the VE seizes the circuit and sends a SETUP-VDL/RES information flow (which identifies the OE, VE, DE, and no-circuit-reservation) to the DE. The DE receives the SETUP-VDL/RES information flow, and then knows that it should provide destination routing treatment for the call. Destination routing treatment could mean routing the call to an exchange within the served area of the DE, or between the DE and a gateway exchange in another network. In particular, the SETUP-VDL/RES information at the DE instructs the DE not to further route the call within the present dynamic routing network, so that circular routing is therefore prohibited.

In the third information flow example marked as ③, the OE accesses the routing table and finds that the via route through a first-VE to DE is the current choice. The OE applies circuit reservation and determines that there is an idle circuit in the OE to first-VE circuit group. The OE seizes an idle circuit in the OE to first-OE circuit group and then sends the SETUP-VDL/RES information (which identifies the OE, first-VE, DE, and no-circuit-reservation) from the OE to the first-VE, and since at the first-VE the call is blocked on the first-VE to DE circuit group a RELEASE-CB information flow is sent back to the OE. In this case the OE accesses the routing table again and finds that the next via route is through a second-VE identified in the routing table, in which case the OE sends a SETUP-VDL/RES information flow (which identifies the OE, second-VE, DE and no-circuit-reservation) to the second-VE in order to set up a two-circuit-group connection from the OE through the second-VE to the DE, without the use of circuit reservation. The second-VE receives the SETUP-VDL/RES information flow and knows to then access the circuit group from the second-VE to the DE. If there is an available circuit, as illustrated in example ③ in Figure B.1, the second-VE seizes the circuit and sends a SETUP-VDL/RES information flow (which identifies the OE, second-VE, DE and no-circuit-reservation) to the DE. The DE receives the SETUP-VDL/RES information flow, and then knows that it should provide destination routing treatment for the call. Destination routing treatment could mean routing the call to an exchange within the served area of the DE, or between the DE and a gateway exchange in another network. In particular, the

SETUP-VDL/RES information at the DE instructs the DE not to further route the call within the present dynamic routing network, so that circular routing is therefore prohibited.

In the fourth information flow example marked as ④, the OE accesses the routing table and finds that the via route through VE to DE is the current choice, and that circuit reservation should be used. The OE then sends the SETUP-VDL/RES information (which identifies the OE, VE, DE and circuit-reservation) from the OE to the VE and then from the VE to the DE in order to set up a two-circuit-group connection from the OE through the VE to the DE, with the use of circuit reservation. The VE receives the SETUP-VDL/RES information flow and knows to then access the circuit group from the VE to the DE. If there is an available circuit, as illustrated in example ④ in Figure B.1, the VE seizes the circuit and sends a SETUP-VDL/RES information flow (which identifies the OE, VE, DE and circuit-reservation) to the DE. The DE receives the SETUP-VDL/RES information flow, and then knows that it should provide destination routing treatment for the call. Destination routing treatment could mean routing the call to an exchange within the served area of the DE, or between the DE and a gateway exchange in another network. In particular, the SETUP-VDL/RES information at the DE instructs the DE not to further route the call within the present dynamic routing network, so that circular routing is therefore prohibited.

In the fifth information flow example marked as ⑤, the OE accesses the routing table and finds that the via route through a first-VE to DE is the current choice, and that circuit reservation should be used. The OE applies circuit reservation and determines that there is an idle circuit in the OE to first-VE circuit group. The OE seizes an idle circuit in the OE to first-OE circuit group and then sends the SETUP-VDL/RES information (which identifies the OE, first-VE, DE and circuit-reservation) from the OE to the first-VE, and since at the first-VE the call is blocked on the first-VE to DE circuit group, a RELEASE-CB information flow is sent back to the OE. In this case the OE accesses the routing table again and finds that the next via route is through a second-VE identified in the routing table, in which case the OE sends a SETUP-VDL/RES information flow (which identifies the OE, second-VE, DE and circuit-reservation) to the second-VE in order to set up a two-circuit-group connection from the OE through the second-VE to the DE, with the use of circuit reservation. The second-VE receives the SETUP-VDL/RES information flow and knows to then access the circuit group from the second-VE to the DE. If there is an available circuit, as illustrated in example ⑤ in Figure B.1, the second-VE seizes the circuit and sends a SETUP-VDL/RES information flow (which identifies the OE, second-VE, DE and circuit-reservation) to the DE. The DE receives the SETUP-VDL/RES information flow, and then knows that it should provide destination routing treatment for the call. Destination routing treatment could mean routing the call to an exchange within the served area of the DE, or between the DE and a gateway exchange in another network. In particular, the SETUP-VDL/RES information at the DE instructs the DE not to further route the call within the present dynamic routing network, so that circular routing is therefore prohibited.

Examples of multiple-circuit-group routing are now given which follow the examples illustrated in 7.4. In the example given in 7.4.1, in routing a call on internetwork E between OE a4 and DE b1, OE a4 routes the call to DE b1 in network B using distributed call-by-call SDR routing table design methods. In that regard OE a4 examines the routing table and first tries to route the call on the direct circuit group a4-b1, and assuming that all a4-b1 circuits are busy then sends a QUERY message to exchange b1 and receives a STATUS response back from DE b1. Based on the status information OE a4 follows the distributed SDR routing table design rules to determine the two-circuit-group alternate route a4-c2-b1 and routes the call to DE b1 via VE c2. In so doing, OE a4 and VE c2 put the forward indicator (identifying OE a4, VE c2, DE b1, no-circuit-reservation) in the call setup message SETUP-VDL/RES. If VE c2 finds that circuit group c2-b1 is busy, it returns control of the call to OE a4 through use of a crankback indicator in the RELEASE-CB release message.

If now OE a4 finds that circuit group d4-b1 has idle capacity based on the status response message from DE b1, then the routing table design rules may result in OE a4 next trying route a4-d3-d4-b1 to DE b1. In that case OE a4 routes the call to VE d3 on circuit group a4-d3, and VE d3 is sent a forward indicator (identifying OE a4, VE d3, VE d4, DE b1, no-circuit-reservation) in the setup message SETUP-VDL/RES indicating that multilink routing is being used to DE b1 via VE d3 and VE d4. In that case VE d3 tries to seize an idle circuit in circuit group d3-d4, and assuming that there is an idle circuit routes the call to VE d4 with a forward indicator (identifying OE a4, VE d3, VE d4, DE b1, no-circuit-reservation) in the SETUP-VDL/RES setup message indicating that multilink routing is being used to exchange b1. VE d4 then routes the call on circuit group d4-b1 to DE b1, which has already been determined to have idle capacity. If, on the other hand, all d3-d4 circuits are busy, then VE d3 returns control of the call to OE a4 through use of a crankback indicator in the RELEASE-CB release message.

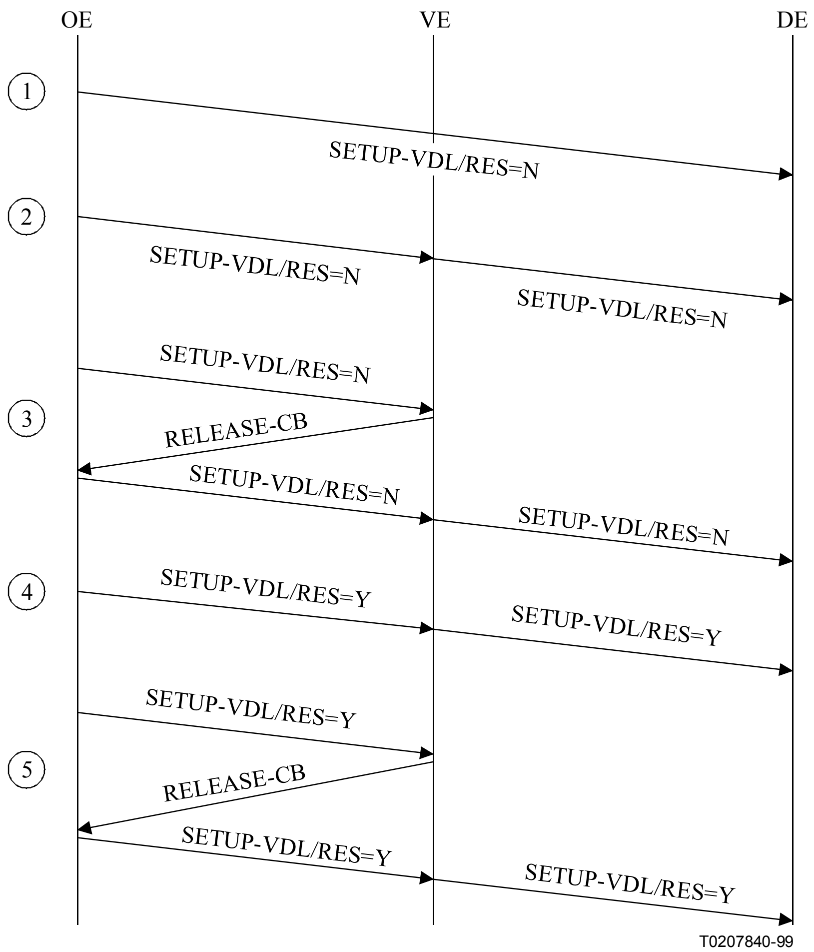


Figure B.1/E.350 – Examples of call control information flow

B.3.2 Examples of routing table design information exchange

Figure B.2 illustrates five information flow examples for routing table design. The first example marked as ① indicates that each exchange periodically (say every ten seconds) sends forward STATUS information to the routing processor (RP), which contains load and traffic status information. The second example marked as ② indicates that the RP sends routing recommendation (RECOM) information to each exchange periodically (say every ten seconds), which contains alternate route information for each OE-DE pair. The third example marked as ③ indicates that each exchange periodically (say every five minutes) sends forward STATUS information to every other exchange, which contains load and traffic status information. The fourth example marked as ④ indicates that the OE sends a forward status QUERY request to the DE. The DE responds to the OE with backward STATUS information, which contains load and traffic status information.

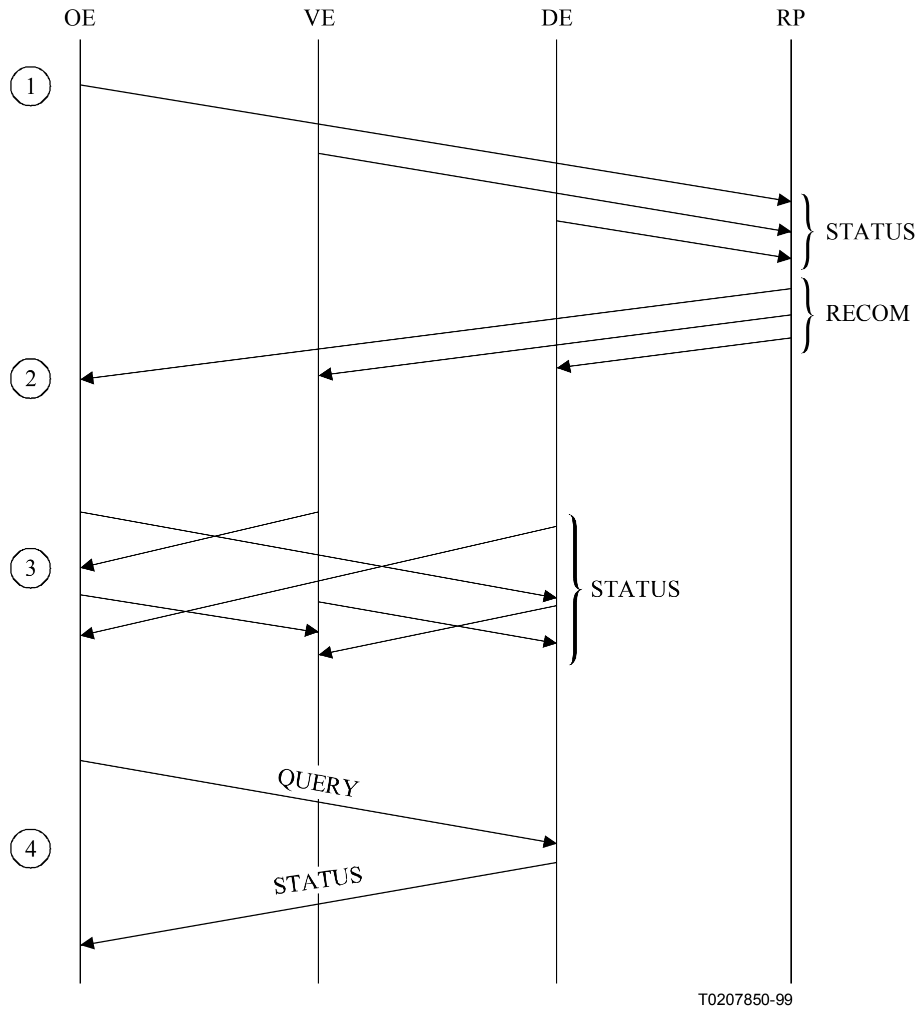


Figure B.2/E.350 – Examples of routing table design information flow

In each case in the above examples, the OE uses the status information in constructing its routing tables. In doing so, the OE implements its particular routing table design method. The examples given in clause 6 and in Annex A illustrate various routing table design methods that may be implemented using the status information.

Use of STATUS information flows and functions are analogous to PTSE messages and routing functionality as in PNNI. However use of QUERY and RECOM information flows gives a degree of flexibility and efficiency found in PSTN dynamic routing methods implemented today.

B.4 Example information flows for interworking dynamic routing methods

Table B.1 gives example information flows for supporting two dynamic routing methods in the same exchange. The table identifies the information flows specific to the combination, and assumes a basic set of needed information flows, which include SETUP-VDL/RES and RELEASE-CB. For example, in the interworking example given in 7.2, EDR is used in internetwork E for routing calls among the exchanges in internetwork E. Therefore exchanges a3 and a4 must support both distributed call-by-call SDR (DC-SDR) and EDR. The information flows required to be supported by exchanges a3 and a4 are given in the corresponding intersecting boxes in Table B.1. Similarly, exchanges b1 and b3 must support information flows for centralized periodic SDR (CP-SDR) and EDR, exchanges c2 and c4 must support information flows only for EDR, and exchanges d3 and d4 must support information flows for TDR and EDR.

Table B.1/E.350 – Example information flows for interworking dynamic routing methods (specific to combination in addition to SETUP – VDL/RES and RLSE-CB)

	FR	TDR	CP-SDR	DP-SDR	DC-SDR	EDR
FR			STATUS RECOM	STATUS	QUERY STATUS	
TDR			STATUS RECOM	STATUS	QUERY STATUS	
CP-SDR			STATUS RECOM	STATUS RECOM	STATUS RECOM QUERY	STATUS RECOM
DP-SDR				STATUS	STATUS QUERY	STATUS
DC-SDR					QUERY STATUS	QUERY STATUS
EDR						

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