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

International routing plan

**QoS routing and related traffic engineering
methods – Call routing and connection routing
methods**

ITU-T Recommendation E.360.2

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ITU-T Recommendation E.360.2

QoS routing and related traffic engineering methods – Call routing and connection routing methods

Summary

The E.360.x series of Recommendations describes, analyzes, and recommends methods which control a network's response to traffic demands and other stimuli, such as link failures or node failures. The functions discussed and recommendations made related to traffic engineering (TE) are consistent with the definition given in the Framework document of the Traffic Engineering Working Group (TEWG) within the Internet Engineering Task Force (IETF):

Internet Traffic Engineering is concerned with the performance optimization of operational networks. It encompasses the measurement, modelling, characterization, and control of Internet traffic, and the application of techniques to achieve specific performance objectives, including the reliable and expeditious movement of traffic through the network, the efficient utilization of network resources, and the planning of network capacity.

The methods addressed in the E.360.x series include call and connection routing, QoS resource management, routing table management, dynamic transport routing, capacity management, and operational requirements. Some of the methods proposed herein are also addressed in or are closely related to those proposed in ITU-T Recs E.170 to E.179 and E.350 to E.353 for routing, E.410 to E.419 for network management and E.490 to E.780 for other traffic engineering issues.

The recommended methods are meant to apply to IP-based, ATM-based, and TDM-based networks, as well as the interworking between these network technologies. Essentially, all of the methods recommended are already widely applied in operational networks worldwide, particularly in PSTN networks employing TDM-based technology. However, these methods are shown to be extensible to packet-based technologies, that is, to IP-based and ATM-based technologies, and it is important that networks which evolve to employ these packet technologies have a sound foundation of methods to apply. Hence, it is the intent that the methods recommended in this series of Recommendations be used as a basis for requirements for specific methods, and, as needed, for protocol development in IP-based, ATM-based, and TDM-based networks to implement the methods.

The methods encompassed in this Recommendation include traffic management through control of routing functions, which include QoS resource management. Results of analysis models are presented which illustrate the tradeoffs between various approaches. Based on the results of these studies, as well as established practice and experience, methods are recommended for consideration in network evolution to IP-based, ATM-based, and/or TDM-based technologies.

Source

ITU-T Recommendation E.360.2 was prepared by ITU-T Study Group 2 (2001-2004) and approved under the WTSA Resolution 1 procedure on 16 May 2002.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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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Introduction

In this Recommendation we assume the separation of "call routing" and signalling for call establishment from "connection (or bearer-path) routing" and signalling for bearer-channel establishment. Call routing protocols primarily translate a number or a name, which is given to the network as part of a call setup, to a routing address needed for the connection (bearer-path) establishment. Call routing protocols are described for example in [Q.2761] for the Broadband ISDN Used Part (B-ISUP) call signalling, [ATM990048] for bearer-independent call control (BICC), or virtual trunking, call signalling, [H.323] for H.323 call signalling, [GR99] for the media gateway control [RFC2805] call signalling, and in [HSSR99] for the session initiation protocol (SIP) call signalling. Connection routing protocols include for example [Q.2761] for B-ISUP signalling, [ATM960055] for PNNI signalling, [ATM960061] for UNI signalling, [DN99] for switched virtual path (SVP) signalling, and [J00] for MPLS constraint-based routing label distribution protocol (CRLDP) signalling.

A specific connection or bearer-path routing method is characterized by the routing table used in the method. The routing table consists of a set of paths and rules to select one path from the route for a given connection request. When a connection request arrives at its originating node (ON), the ON implementing the routing method executes the path selection rules associated with the routing table for the connection to determine a selected path from among the path candidates in the route for the connection request. In a particular routing method, the path selected for the connection request is governed by the connection routing, or path selection, rules. Various path selection methods are discussed: fixed routing (FR) path selection, time-dependent routing (TDR) path selection, state-dependent routing (SDR) path selection, and event-dependent routing (EDR) path selection.

ITU-T Recommendation E.360.2

QoS routing and related traffic engineering methods – Call routing and connection routing methods

1 Scope

The E.360.x series of Recommendations describes, analyzes, and recommends methods which control a network's response to traffic demands and other stimuli, such as link failures or node failures. The functions discussed and recommendations made related to traffic engineering (TE) are consistent with the definitions given in the Framework document of the Traffic Engineering Working Group (TEWG) within the Internet Engineering Task Force (IETF):

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The methods addressed in the E.360.x series include call and connection routing, QoS resource management, routing table management, dynamic transport routing, capacity management, and operational requirements. Some of the methods proposed herein are also addressed in or are closely related to those proposed in ITU-T Recs E.170 to E.179 and E.350 to E.353 for routing, E.410 to E.419 for network management, E.490 to E.780 for other traffic engineering issues.

The recommended methods are meant to apply to IP-based, ATM-based, and TDM-based networks, as well as the interworking between these network technologies. Essentially, all of the methods recommended are already widely applied in operational networks worldwide, particularly in PSTN networks employing TDM-based technology. However, these methods are shown to be extensible to packet-based technologies, that is, to IP-based and ATM-based technologies, and it is important that networks which evolve to employ these packet technologies, have a sound foundation of methods to apply. Hence, it is the intent that the methods recommended in this series of Recommendations be used as a basis for requirements for specific methods and, as needed, for protocol development in IP-based, ATM-based, and TDM-based networks, to implement the methods.

Hence the methods encompassed in this series of Recommendations include:

- traffic management through control of routing functions, which include call routing (number/name translation to routing address), connection routing, QoS resource management, routing table management, and dynamic transport routing;
- capacity management through control of network design, including routing design;
- operational requirements for traffic management and capacity management, including forecasting, performance monitoring, and short-term network adjustment.

Results of analysis models are presented which illustrate the tradeoffs between various approaches. Based on the results of these studies as well as established practice and experience, TE methods are recommended for consideration in network evolution to IP-based, ATM-based, and/or TDM-based technologies.

2 References

See clause 2 of Rec. ITU-T E.360.1.

3 Definitions

See clause 3 of Rec. ITU-T E.360.1.

4 Abbreviations

See clause 4 of Rec. ITU-T E.360.1.

5 Call routing methods

Call routing entails number (or name) translation to a routing address, which is then used for connection establishment. Routing addresses can consist, for example, of:

- a) E.164 ATM end system addresses (AESAs) [E.191];
- b) network routing addresses (NRAs) [E.353]; and/or
- c) IP addresses [S94].

As discussed in ITU-T Rec. E.360.4, a TE requirement is the need for carrying E.164-AESA addresses, NRAs, and IP addresses in the connection-setup information element (IE). In that case, E.164-AESA addresses, NRAs, and IP addresses become the standard addressing method for interworking across IP-, ATM-, and TDM-based networks. Another TE requirement is that a call identification code (CIC) be carried in the call-control and bearer-control connection-setup IEs in order to correlate the call-control setup with the bearer-control setup ([Q.1901], [ATM990048]). Carrying these additional parameters in the Signalling System 7 (SS7) ISDN User Part (ISUP) connection-setup IEs is referred to as the bearer independent call control (BICC) protocol.

Number (or name) translation, then, should result in the E.164-AESA addresses, NRAs, and/or IP addresses. NRA formats are covered in [E.353], and IP-address formats in [S94]. The AESA address has a 20-byte format as shown in Figure 1a. [E.191].

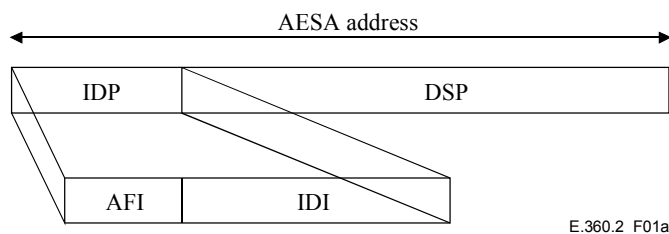


Figure 1a/E.360.2 – AESA address structure

The IDP is the initial domain part and the DSP is the domain specific part. The IDP is further subdivided into the AFI and IDI. The IDI is the initial domain identifier and can contain the 15-digit E.164 address if the AFI is set to 45. AFI is the authority and format identifier and determines what kind of addressing method is followed and, based on the 1 octet AFI value, the length of the IDI and DSP fields can change. The E.164-AESA address is used to determine the path to the destination endpoint. E.164-AESA addressing for B-ISDN services is supported in ATM networks using PNNI, through use of the above AESA format. In this case the E.164 part of the AESA address occupies the 8 octet IDI, and the 11 octet DSP can be used at the discretion of the network operator (perhaps for sub-addresses). The above AESA structure also supports AESA DCC (data country code) and AESA ICD (international code designator) addressing formats.

Within the IP network, routing is performed using IP addresses. Translation databases, such as based on domain name system (DNS) technology [F00], are used to translate the E.164 numbers/names for calls to IP addresses for routing over the IP network. The IP address is a 4-byte address structure as shown in Figure 1b.

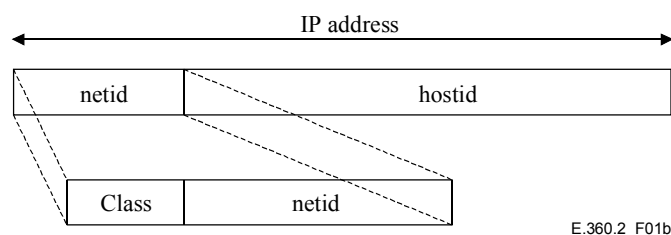


Figure 1b/E.360.2 – IP address structure

There are five classes of IP addresses. Different classes have different field lengths for the network identification field. Classless inter-domain routing (CIDR) allows blocks of addresses to be given to service providers in such a manner as to provide efficient address aggregation. This is accompanied by capabilities in the BGP4.0 protocol for efficient address advertisements [RL00], [S94].

6 Connection (bearer-path) routing methods

Connection routing is characterized by the routing table used in the method and rules to select one path from the route for a given connection or bandwidth-allocation request. When a connection/bandwidth-allocation request is initiated by an ON, the ON implementing the routing method executes the path selection rules associated with the routing table for the connection/bandwidth-allocation to find an admissible path from among the paths in the route that satisfies the connection/bandwidth-allocation request. In a particular routing method, the selected path is determined according to the rules associated with the routing table. In a network with originating connection/bandwidth-allocation control, the ON maintains control of the connection/bandwidth-allocation request. If crankback/bandwidth-not-available is used, for example, at a via node (VN), the preceding node maintains control of the connection/bandwidth-allocation request even if the request is blocked on all the links outgoing from the VN.

Here we are discussing network-layer connection routing (sometimes referred to as "layer-3" routing), as opposed to the link-layer logical-link ("layer-2") routing or physical-layer ("layer-1") routing. In the Recommendation the term "link" will normally mean "logical-link". In ITU-T Rec. E.360.5 we address logical-link routing.

The network-layer (layer-3) connection routing methods addressed include those discussed in:

- Open Shortest Path First (OSPF), Border Gateway Protocol (BGP), and Multiprotocol Label Switching (MPLS) for IP-based routing methods;
- User-to-Network Interface (UNI), Private Network-to-Network Interface (PNNI), ATM Inter-Network Interface (AINI), and Bandwidth Modify for ATM-based routing methods; and
- ITU-T Recs E.170, E.350, and E.351 for TDM-based routing methods.

In an IP network, logical links called traffic trunks can be defined which consist of MPLS label switched paths (LSPs) between the IP nodes. Traffic trunks are used to allocate the bandwidth of the logical links to various node pairs. In an ATM network, logical links called virtual paths (VPs) (the equivalent of traffic trunks) can be defined between the ATM nodes, and VPs can be used to allocate the bandwidth of the logical links to various node pairs. In a TDM network, the logical links consist of trunk groups between the TDM nodes.

A sparse logical link network is typically used with IP and ATM technology, as illustrated in Figure 2, and FR, TDR, SDR, and EDR can be used in combination with multilink shortest path selection.

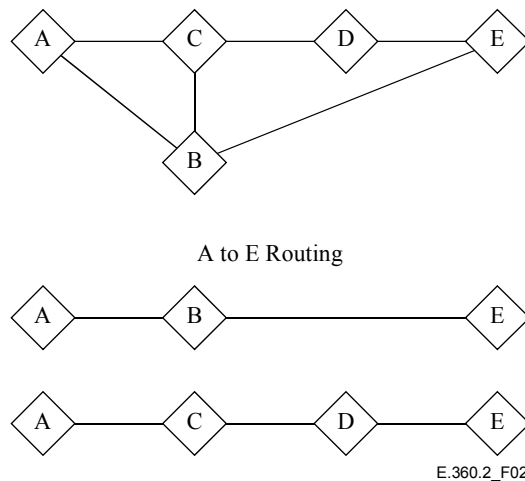


Figure 2/E.360.2 – Sparse logical network topology with connections routed on multilink paths

A meshed logical-link network is typically used with TDM technology, but can be used also with IP or ATM technology as well, and selected paths are normally limited to 1 or 2 logical links, or trunk groups, as illustrated in Figure 3.

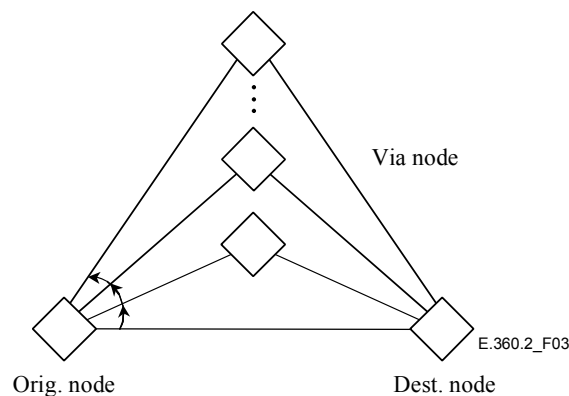


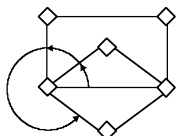
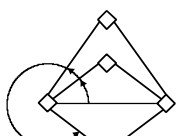
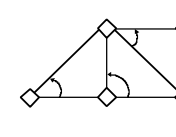
Figure 3/E.360.2 – Mesh logical network topology with connections routed on 1- and 2-link paths

Paths may be set up on individual connections (or "per-flow") for each call request, such as on a switched virtual circuits (SVC). Paths may also be set up for bandwidth-allocation requests associated with "bandwidth pipes" or traffic trunks, such as on switched virtual paths (SVPs) in ATM-based networks or constraint-based routing label switched paths (CRLSPs) in IP-based networks. Paths are determined by (normally proprietary) algorithms based on the network topology and reachable address information. These paths can cross multiple peer groups in ATM-based networks, and multiple autonomous systems (ASs) in IP-based networks. An ON may select a path from the routing table based on the routing rules and the QoS resource management criteria, described in ITU-T Rec. E.360.3, which must be satisfied on each logical-link in the path. If a link is not allowed based on the QoS criteria, then a release with crankback/bandwidth-not-available parameter is used to signal that condition to the ON in order to return the connection/bandwidth-allocation request to the ON, which may then select an alternate path. In addition to controlling bandwidth allocation, the QoS resource management procedures can check end-to-end transfer delay, delay variation, and transmission quality considerations such as loss, echo, and noise.

When source routing is used, setup of a connection/bandwidth-allocation request is achieved by having the ON identify the entire selected path including all VNs and DN in the path in a designated-transit-list (DTL) or explicit-route (ER) parameter in the connection-setup IE. If the QoS or traffic parameters cannot be realized at any of the VNs in the connection setup request, then the VN generates a crankback (CBK)/bandwidth-not-available (BNA) parameter in the connection-release IE which allows a VN to return control of the connection request to the ON for further alternate routing. In ITU-T Rec. E.360.4, the DTL/ER and CBK/BNA elements are identified as being required for interworking across IP-, ATM-, and TDM-based networks.

As noted earlier, connection routing, or path selection, methods are categorized into the following four types: 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 paragraphs. Examples of each of these path selection methods are illustrated in Figures 4a and 4b and discussed in the following clauses.

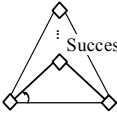
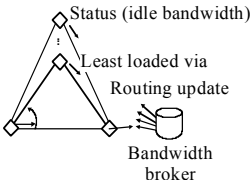
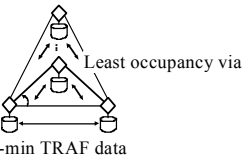
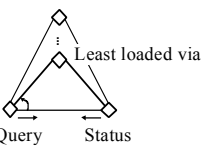
Dynamic routing allows routing tables to be changed dynamically, either in an off-line, preplanned, time-varying manner, as in TDR, or on-line, in real time, as in SDR or EDR. With off-line, pre-planned TDR path selection methods, routing patterns contained in routing tables might change every hour or at least several times a day to respond to measured hourly shifts in traffic loads, and in general, TDR routing tables change with a time constant normally greater than a call/traffic-flow holding time. A typical TDR routing method may change routing tables every hour, which is longer than a typical voice call/traffic-flow holding time of a few minutes. Three implementations of TDR dynamic path selection are illustrated in Figure 4a, which shows multilink path routing, 2-link path routing, and progressive routing.

Dynamic multilink path routing		• One-link, two-link and multilink paths allowed • Paths hunted according to various rules: cyclic, cyclic block (CGH), skip-one-path, sequential • Path order changed with time; bandwidth broker predetermines routes based on traffic • Crankback from via node to originating node if blocked
Dynamic two-link path routing		• One-link and two-link paths allowed • Paths hunted according to various rules: cyclic, cyclic block (CGH), skip-one-path, sequential • Path order changed with time; bandwidth broker predetermines routes based on traffic • Crankback from via node to originating node if blocked
Dynamic progressive routing		• One-link, two-link, and multilink paths allowed • Destination based link sequence hunted at each node • Link hunt order changed with time at originating node; bandwidth broker predetermines routes based on traffic • Progressive toward destination; no crankback or return to previous node

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Figure 4a/E.360.2 – TDR dynamic path selection methods

TDR routing tables are preplanned, preconfigured, and recalculated perhaps each week within the capacity management network design function. Real-time dynamic path selection does not depend on precalculated routing tables. Rather, the node or centralized bandwidth broker senses the immediate traffic load and if necessary searches out new paths through the network possibly on a per-traffic-flow basis. With real-time path selection methods, routing tables change with a time constant on the order of or less than a call/traffic-flow holding time. As illustrated in Figure 4b, on-line, real-time path selection methods include EDR and SDR.

Event dependent routing		• Select primary path, then currently successful via path • Randomly select new via path when call is blocked • STT method: allow up to N crankbacks to find successful via path
State dependent routing (centralized, periodic)		• Select primary path, then least loaded via path recommended by bandwidth broker • Each node sends periodic link status to bandwidth broker • Each node receives periodic routing update from bandwidth broker
State dependent routing (distributed, periodic)		• Periodic (e.g. 5-minute) traffic data exchange • Select primary path, then least occupancy via path
State dependent routing (distributed, call-by-call)		• Select primary path, then least loaded via path based on real-time status • Originating node queries terminating node for link status • Routing changes call-by-call

E.360.2_F04b

Figure 4b/E.360.2 – EDR and SDR dynamic path selection methods

7 Hierarchical Fixed Routing (FR) path selection

Hierarchical fixed routing (FR) is an important routing topology employed in all types of networks, including IP-, ATM-, and TDM-based networks. In IP-based networks, there is often a hierarchical relationship among different "areas", or sub-networks. Hierarchical multi-domain (or multi-area or multi-autonomous-system) topologies are normally used with IP routing protocols (OSPF, BGP) and ATM routing protocols (PNNI), as well as within almost all TDM-based network routing topologies.

For example, in Figure 4c, BB1 and BB2 could be backbone nodes in a "backbone area", and AN1 and AN2 could be access nodes in separate "access areas" distinct from the backbone area. Routing between the areas follows a hierarchical routing pattern, while routing within an area follows an interior gateway protocol (IGP), such as OSPF plus MPLS. Similarly, in ATM-based networks the same concept exists, but here the "areas" are called "peer-groups", and for example, the IGP used within peer-groups could be PNNI. In TDM-based networks, the routing between sub-networks, for example, metropolitan-area-networks and long-distance networks, is normally hierarchical, as in IP- and ATM-based networks, and the IGP in TDM-based networks could be either hierarchical or dynamic routing. We now discuss more specific attributes and methods for hierarchical FR path selection.

In a FR method, a routing pattern is fixed for a connection request. A typical example of fixed routing is a conventional, TDM-based, hierarchical alternate routing pattern where the route and route selection sequence are determined on a preplanned basis and maintained over a long period of time. Hierarchical FR is illustrated in Figure 4c. FR is more efficiently applied, however, when the network is nonhierarchical, or flat, as compared to the hierarchical structure [A98].