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HUMAN FACTORS

International routing plan

**QoS routing and related traffic engineering
methods – Routing table management methods
and requirements**

ITU-T Recommendation E.360.4

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ITU-T Recommendation E.360.4

QoS routing and related traffic engineering methods – Routing table management methods and requirements

Summary

The E.360.x series of Recommendations describes, analyses, 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.360.4 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

Routing table management typically entails the automatic generation of routing tables based on network topology and other information such as status. Routing table management information, such as topology update, status information, or routing recommendations, is used for purposes of applying the routing table design rules for determining path choices in the routing table. This information is exchanged between one node and another node, such as between the originating node (ON) and destination node (DN), for example, or between a node and a network element such as a bandwidth-broker processor (BBP). This information is used to generate the routing table, and then the routing table is used to determine the path choices used in the selection of a path.

This automatic generation function is enabled by the automatic exchange of link, node, and reachable address information among the network nodes. In order to achieve automatic update and synchronization of the topology database, which is essential for routing table management, IP- and ATM-based networks already interpret HELLO protocol mechanisms to identify links in the network. For topology database synchronization, the link state advertisement (LSA) is used in IP-based networks, and the PNNI topology-state-element (PTSE) exchange is used in ATM-based networks to automatically provision nodes, links, and reachable addresses in the topology database. Use of a single peer group/autonomous system for topology update leads to more efficient routing and easier administration, and is best achieved by minimizing the use of topology state (LSA and PTSE) flooding for dynamic topology state information. It is required in 8.4 that a topology state element (TSE) be developed within TDM-based networks. When this is the case, then the HELLO and LSA/TSE/PTSE parameters will become the standard topology update method for interworking across IP-, ATM-, and TDM-based networks.

Status update methods are required for use in routing table management within and between network types. In TDM-based networks, status updates of link and/or node status are used [E.350], [E.351]. Within IP- and ATM-based networks, status updates are provided by a flooding mechanism. It is required in 8.4 that a routing status element (RSE) be developed within TDM-based networks, which will be compatible with the PNNI topology state element (PTSE) in ATM-based networks and the link state advertisement (LSA) element in IP-based networks. When this is the case, then the RSE/PTSE/LSA parameters will become the standard status update method for interworking across TDM-, ATM-, and IP-based networks.

Query for status methods are required for use in routing table management within and between network types. Such methods allow efficient determination of status information, as compared to flooding mechanisms. Such query for status methods are provided in TDM-based networks [E.350], [E.351]. It is required in 8.4 that a routing query element (RQE) be developed within ATM-based and IP-based networks. When this is the case, then the RQE parameters will become the standard query for status method for interworking across TDM-, ATM-, and IP-based networks.

Routing recommendation methods are proposed for use in routing table management within and between network types. For example, such methods provide for a database, such as a BBP, to advertise recommended paths to network nodes based on status information available in the database. Such routing recommendation methods are provided in TDM-based networks [E.350], [E.351]. It is required in 8.4 that a routing recommendation element (RRE) be developed within ATM-based and IP-based networks. When this is the case, then the RRE parameters will become the standard query for status method for interworking across TDM-, ATM-, and IP-based networks.

ITU-T Recommendation E.360.4

QoS routing and related engineering methods – Routing table management methods and requirements

1 Scope

The E.360.x series of Recommendations describes, analyses, 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 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.

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/E.360.1.

3 Definitions

See clause 3/E.360.1.

4 Abbreviations

See clause 4/E.360.1.

5 Routing table management for IP-based networks

IP networks typically run the OSPF protocol for intra-domain routing [RFC2328], [S95] and the BGP protocol for inter-domain routing [RL00], [S95]. OSPF and BGP are designed for routing of datagram packets carrying multimedia internet traffic. Within OSPF, a link-state update topology exchange mechanism is used by each IP node to construct its own shortest path routing tables. Through use of these routing tables, the IP nodes match the destination IP address to the longest match in the table and thereby determine the shortest path to the destination for each IP packet. In current OSPF operation, this shortest path remains fixed unless a link is added or removed (e.g. fails), and/or an IP node enters or leaves the network. However, the protocol allows for possibly more sophisticated dynamic routing mechanisms to be implemented. MPLS is currently being developed as a means by which IP networks may provide connection oriented, QoS-routing services, such as with ATM layer-2 switching technology [RVC99], and differentiated services (DiffServ) [RFC2475], [ST98] is being developed to provide priority queuing control in IP-based networks. MPLS and DiffServ both provide essential capabilities for QoS resource management, as discussed in ITU-T Rec. E.360.3.

These IP-based protocols provide for:

- a) exchange of node and link status information;
- b) automatic update and synchronization of topology databases; and
- c) fixed and/or dynamic route selection based on topology and status information.

For topology database synchronization, each node in an IP-based OSPF/BGP network exchanges HELLO packets with its immediate neighbors and thereby determines its local state information. This state information includes the identity and group membership of the node's immediate neighbors, and the status of its links to the neighbors. Each node then bundles its state information in LSAs, which are reliably flooded throughout the autonomous system (AS), or group of nodes exchanging routing information and using a common routing protocol, which is analogous to the PNNI peer group used in ATM-based networks. The LSAs are used to flood node information, link state information and reachability information. As in PNNI, some of the topology state information is static and some is dynamic. In order to allow larger AS group sizes, a network can use OSPF in such a way so as to minimize the amount of dynamic topology state information flooding, such as available link bandwidth, by setting thresholds to values that inhibit frequent updates.

IP-based routing of connection/bandwidth-allocation requests and QoS-routing support are in the process of standardization, primarily within the MPLS and DiffServ [RFC2475], [ST98] activities in the IETF. IGPs, such as OSPF, are still applicable to determine routing in an MPLS architecture, but are only one of many proposed capabilities to implement traffic engineering (TE) with MPLS. ITU-T Rec. E.360.1 [ACEWX00] calls for many TE mechanisms, distributed, centralized, off-line, on-line, time-dependent, state-dependent, event-dependent, some, but not all, of which would involve interior gateway protocols such as OSPF.

As described in ITU-T Rec. E.360.1, a number of enhancements are needed to conventional link state IGPs, such as OSPF and IS-IS, to allow them to distribute additional state information required for constraint-based routing. Essentially, these enhancements require the propagation of additional information in link state advertisements. Specifically, in addition to normal link-state information, an enhanced IGP is required to propagate topology state information needed for constraint-based

routing. Some of the additional topology state information includes link attributes such as reservable bandwidth and link resource class attribute (an administratively specified property of the link). Deployment of MPLS for traffic engineering applications has commenced in some service provider networks. One operational scenario is to deploy MPLS in conjunction with an IGP (IS-IS-TE or OSPF-TE) that supports the traffic engineering extensions, in conjunction with constraint-based routing for explicit route computations, and a signalling protocol (e.g. RSVP-TE or CRLDP) for LSP instantiation.

In contemporary MPLS traffic engineering contexts, network administrators specify and configure link attributes and resource constraints such as maximum reservable bandwidth and resource class attributes for links (interfaces) within the MPLS domain. A link state protocol that supports TE extensions (IS-IS-TE or OSPF-TE) is used to propagate information about network topology and links attributes to all routers in the routing area. Network administrators also specify all the LSPs that are to originate at each router. For each LSP, the network administrator specifies the destination node and the attributes of the LSP which indicate the requirements that are to be satisfied during the path selection process. Each router then uses a local constraint-based routing process to compute explicit paths for all LSPs originating from it. Subsequently, a signalling protocol is used to instantiate the LSPs. By assigning proper bandwidth values to links and LSPs, congestion caused by uneven traffic distribution can generally be avoided or mitigated. In order to perform constraint-based routing on a per-class basis for LSPs, the conventional IGPs (e.g. IS-IS and OSPF) should provide extensions to propagate per-class resource information.

There are also proposals for using more centralized policy models to support TE implementation [WHJ00], [IYBKQ00]. As described in ITU-T Rec. E.360.1, off-line (and on-line) TE considerations would be of limited utility if the network could not be controlled effectively to implement the results of TE decisions and to achieve desired network performance objectives. Capacity augmentation is a coarse-grained solution to traffic engineering issues. However, it is simple and may be advantageous if bandwidth is abundant and cheap, or if the current or expected network workload demands it. However, bandwidth is not always abundant and cheap, and the workload may not always demand additional capacity. Adjustments of administrative weights and other parameters associated with routing protocols provide finer grained control, but is difficult to use and imprecise because of the routing interactions that occur across the network. In certain network contexts, more flexible, finer grained approaches which provide more precise control over the mapping of traffic to routes, and over the selection and placement of routes, may be appropriate and useful. Control mechanisms can be manual (e.g. administrative configuration), partially automated (e.g. scripts) or fully automated (e.g. policy-based management systems). Automated mechanisms are particularly required in large-scale networks. Multi-vendor interoperability can be facilitated by developing and deploying standardized management systems (e.g. standard MIBs) and policies (PIBs) to support the control functions required to address traffic engineering objectives such as load distribution and protection/restoration.

MPLS depends on layer 3 mechanisms to determine LSP routes, and also the way that the routes are used. That is, MPLS has no routing of its own built in (it is "between layer 3 and layer 2"). Unlike layer 3 protocols, MPLS lacks addressing and routing components. It has to rely on IP, OSPF/BGP etc. for that. MPLS is not a layer 2 protocol either as it does not have a single format for data transmission which is a requirement for a layer 2 protocol. How exactly the OSPF/IS-IS extensions get used, how policy-based capabilities get used, etc., to determine MPLS routing, is going to be a matter of vendor implementation. What is emerging are a lot of different capabilities to implement MPLS/TE in many ways, and service providers may provide requirements for a standardized "generic TE method", somewhat like a generic CAC in the ATM context discussed below. These standards requirement would then be used to drive the vendor implementations in the direction of network operator requirements and vendor interoperability.

The following assumptions are made regarding the outcomes of these IP-based routing standardization directions:

- a) Call routing in support of connection establishment functions on a per-connection basis to determine the routing address based on a name/number translation, and uses a protocol such as H.323 [H.323], or the session initiation protocol (SIP) [RFC2543]. It is assumed that the call routing protocol interworks with the broadband ISDN user part (B-ISUP) [Q.2761] and bearer-independent call control (BICC) protocols [Q.1901] to accommodate setup and release of connection requests.
- b) Connection/bandwidth-allocation routing in support of bearer-path selection is assumed to employ OSPF/BGP path selection methods in combination with MPLS. MPLS employs a constraint-based routing label distribution protocol (CRLDP) [J00], [CDFFSV99] or a resource reservation protocol (RSVP) [RFC2205] to establish constraint-based routing label switched paths (CRLSPs). Bandwidth allocation to CRLSPs is managed in support of QoS resource management, as discussed in ITU-T Rec. E.360.3.
- c) The MPLS label request message (equivalent to the setup message) carries the explicit route parameter specifying the via nodes (VNs) and destination node (DN) in the selected CRLSP and the depth-of-search (DoS) parameter specifying the allowed bandwidth selection threshold on a link.
- d) The MPLS notify (equivalent to the release) message is assumed to carry the crankback/bandwidth-not-available parameter specifying return of control of the connection/bandwidth-allocation request to the originating node (ON), for possible further alternate routing to establish additional CRLSPs.
- e) Call control routing is coordinated with connection/bandwidth-allocation for bearer-path establishment.
- f) Reachability information is exchanged between all nodes. To provision a new IP address, the node serving that IP address is provisioned. The reachability information is flooded to all nodes in the network using the OSPF LSA flooding mechanism.
- g) The ON performs destination name/number translation, service processing, and all steps necessary to determine the routing table for the connection/bandwidth-allocation request across the IP network. The ON makes a connection/bandwidth-allocation request admission if bandwidth is available and places the connection/bandwidth-allocation request on a selected CRLSP.

IP-based networks employ an IP addressing method to identify node endpoints [S94]. A mechanism is needed to translate E.164 AESAs to IP addresses in an efficient manner. Work is in progress [F00], [B91] to interwork between IP addressing and E.164 numbering/addressing, in which a translation database is required, based on domain name system (DNS) technology, to convert E.164 addresses to IP addresses. With such a capability, IP nodes could make this translation of E.164 AESAs directly, and thereby provide interworking with TDM- and ATM-based networks which use E.164 numbering and addressing. If this is the case, then E.164 AESAs could become a standard addressing method for interworking across IP-, ATM-, and TDM-based networks.

As stated above, path selection in an IP-based network is assumed to employ OSPF/BGP in combination with the MPLS protocol that functions efficiently in combination with call control establishment of individual connections. In OSPF-based layer 3 routing, as illustrated in Figure 1, an ON N1 determines a list of shortest paths by using, for example, Dijkstra's algorithm.