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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 – Transport routing methods

ITU-T Recommendation E.360.5

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ITU-T Recommendation E.360.5

QoS routing and related traffic engineering methods –Transport 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.360.5 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

This Recommendation describes and analyzes transport network architectures in light of evolving technology for integrated broadband networks. Dynamic transport routing offers advantages of simplicity of design and robustness to load variations and network failures. Dynamic transport routing can combine with dynamic traffic routing to shift transport bandwidth among node pairs and services through use of flexible transport switching technology. Dynamic transport routing can provide automatic link provisioning, diverse link routing, and rapid link restoration for improved transport capacity utilization and performance under stress.

We present reliable transport routing models to achieve reliable network design, so as to provide service for predefined restoration objectives for any transport link or node failure in the network and continue to provide connections to customers with essentially no perceived interruption of service. We show that robust routing techniques such as dynamic traffic routing, multiple ingress/egress routing, and logical link diversity routing improve response to node or transport failures.

Cross-connect devices, such as optical cross-connects (OXC), are able to route transport channels, for example OC48 channels, onto different higher-capacity transport links such as an individual WDM channel on a fiberoptic cable. Transport paths can be rearranged at high speed using OXC, typically within tens of milliseconds switching times. These OXC can reconfigure logical transport capacity on demand, such as for peak day traffic, weekly redesign of link capacity, or emergency restoration of capacity under node or transport failure. Rearrangement of logical link capacity involves reallocating both transport bandwidth and node terminations to different links. OXC technology is amenable to centralized traffic management.

There is recent work in extending MPLS control capabilities to the setup of layer 2 logical links through OXC, this effort dubbed multiprotocol lambda switching, after the switching of wavelengths in dense wavelength division multiplexing (DWDM) technology [ARDC99].

ITU-T Recommendation E.360.5

QoS routing and related traffic engineering methods –Transport 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 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 of ITU-T Rec. E.360.1.

3 Definitions

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

4 Abbreviations

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

5 Dynamic transport routing principles

An important element of network architecture is the relationship between the transport network and the traffic network. An illustration of a transport network is shown in Figures 1 and 2 illustrates the mapping of layer-2 logical links in the traffic network onto the layer-1 physical transport network of Figure 1. Some logical links overlay two or more fiber-backbone links. For example, in Figure 1, logical link AD traverses fiber-backbone links AB, BC, and CD.

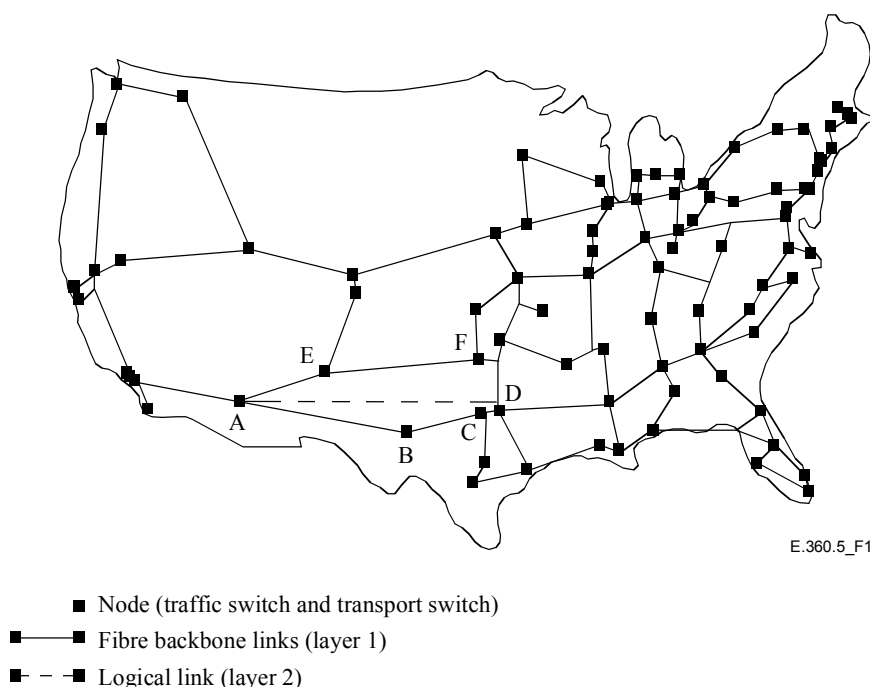
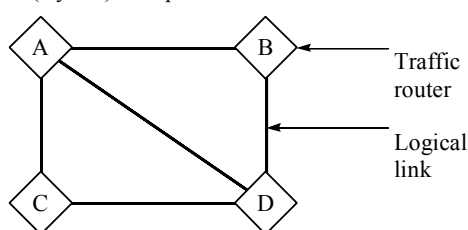


Figure 1/E.360.5 – Transport network model

Figure 2 further illustrates the difference between the physical transport network (layer 1) and the logical transport network (layer 2). Logical links are individual logical connections between network nodes, which make up the logical link connections and are routed on the physical transport network. Logical links can be provisioned at given rates, such as T1, OC3, OC12, OC48, OC192, etc., and is dependent on the level of traffic demand between nodes.

Logical (layer 2) transport network view



Physical (layer 1) transport network view

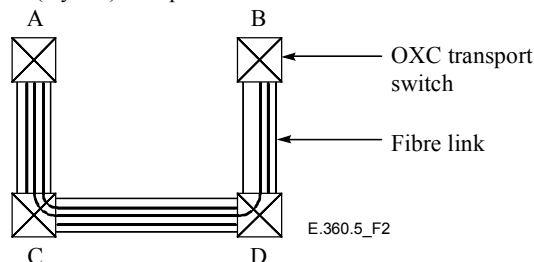


Figure 2/E.360.5 – Logical (layer 2) and physical (layer 1) transport networks

Figure 2 indicates that a direct logical link is obtained by cross-connecting through a transport switching location. Thus, the traffic network is a logical network overlaid on a sparse physical one. A cross-connect device is traversed at each network node on a given logical link path over layer-1 physical transport links, as illustrated in Figure 2. This is particularly promising when such a device has low cost.

It is clear from Figures 1 and 2 that in a highly interconnected traffic network, or logical transport network, many node pairs may have a "direct" logical link connection where none exists in the physical transport network. In this case, a direct logical link is obtained by cross-connecting through a transport switching location, such as an OXC. This is distinct from the traffic routing situation in which a bearer connection is actually switched at an intermediate location. This distinction between cross-connecting and switching is a bit subtle, but it is fundamental to traffic routing of calls and transport routing of logical links. Referring to Figure 2, we illustrate one of the logical inconsistencies we encounter when we design the traffic network to be essentially separate from the transport network. On the alternative traffic path from node B to node D through A, the physical path is, in fact, up and back from B to A (a phenomenon known as "backhauling") and then across from B to D. The sharing of capacity by various traffic loads in this way actually increases the efficiency of the network because the backhauled capacity to and from B and A is only used when no direct A-to-B or A-to-D traffic wants to use it. It is conceivable that under certain conditions, capacity could be put to more efficient use, and this is studied in this Recommendation.

Hence, a logical link connection is obtained by cross-connecting through transport switching devices, such as OXCs, and this is distinct from per-flow routing, which switches a call on the logical links at each node in the call path. In this way, the logical transport network is overlaid on a sparser physical transport network. In ITU-T Rec. E.360.2 we discussed a wide variety of dynamic traffic routing methods. Dynamic transport routing methods incorporate dynamic path selection which seeks out and uses idle network capacity by using frequent, perhaps call-by-call, traffic and transport routing table update decisions. The trend in both traffic and transport routing architecture is toward greater flexibility in resource allocation, which includes transport and switching resource allocation. A fixed transport routing architecture may have dynamic traffic routing but fixed transport routing of logical link capacity. In a dynamic transport routing architecture, however, the logical link capacities can be rapidly rearranged that is, they are not fixed.

With dynamic transport routing, the logical transport bandwidth is shifted rapidly at layer 2 among node pairs and services through the use of dynamic cross-connect devices. In this case, the layer-1 physical fiber-link bandwidth is allocated among the layer-2 logical links. Bandwidth allocation at layer 3 also creates the equivalent of direct links, and we refer to these links as traffic trunks, which in turn comprise virtual networks (VNETs) as described in ITU-T Rec. E.360.3. Traffic trunks can be implemented, for example, by using MPLS label switched paths (LSPs). Bandwidth is allocated to traffic trunks in accordance with traffic demands, and normally not all logical link bandwidth is assigned; thus, there is a pool of unassigned bandwidth. In cases of traffic overload for a given node pair, the node first sets up calls on the traffic trunk that connects the node pair. If that is not possible, the node then sets up calls on the available pool of bandwidth. If there is available bandwidth, then the bandwidth is allocated to the traffic trunk and used to set up the call. If bandwidth is not available, then the layer-2 logical link bandwidth might be dynamically increased by the bandwidth broker, and then allocated to the traffic trunk and finally, the call. In a similar manner, in the event that bandwidth is underutilized in a traffic trunk, excess bandwidth is released to the available pool of bandwidth and then becomes available for assignment to other node pairs. If logical link bandwidth is sufficiently underutilized, the bandwidth might be returned to the available pool of layer-1 fiber-link bandwidth. The bandwidth broker reassigns network resources on a dynamic basis, through analysis of traffic data collected from the individual nodes.

In the dynamic transport architecture, we allow logical link between the various nodes to be rearranged rapidly, such as by hour of the day, or perhaps in real time. Dynamic transport routing capability enables rearrangement of the logical link capacities on demand. This capability appears