



INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

E.360.6

(05/2002)

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

International routing plan

QoS routing and related traffic engineering methods – Capacity management methods

ITU-T Recommendation E.360.6

ITU-T E-SERIES RECOMMENDATIONS

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

INTERNATIONAL OPERATION	
Definitions	E.100–E.103
General provisions concerning Administrations	E.104–E.119
General provisions concerning users	E.120–E.139
Operation of international telephone services	E.140–E.159
Numbering plan of the international telephone service	E.160–E.169
International routing plan	E.170–E.179
Tones in national signalling systems	E.180–E.189
Numbering plan of the international telephone service	E.190–E.199
Maritime mobile service and public land mobile service	E.200–E.229
OPERATIONAL PROVISIONS RELATING TO CHARGING AND ACCOUNTING IN THE INTERNATIONAL TELEPHONE SERVICE	
Charging in the international telephone service	E.230–E.249
Measuring and recording call durations for accounting purposes	E.260–E.269
UTILIZATION OF THE INTERNATIONAL TELEPHONE NETWORK FOR NON-TELEPHONY APPLICATIONS	
General	E.300–E.319
Phototelegraphy	E.320–E.329
ISDN PROVISIONS CONCERNING USERS	E.330–E.349
INTERNATIONAL ROUTING PLAN	E.350–E.399
NETWORK MANAGEMENT	
International service statistics	E.400–E.409
International network management	E.410–E.419
Checking the quality of the international telephone service	E.420–E.489
TRAFFIC ENGINEERING	
Measurement and recording of traffic	E.490–E.505
Forecasting of traffic	E.506–E.509
Determination of the number of circuits in manual operation	E.510–E.519
Determination of the number of circuits in automatic and semi-automatic operation	E.520–E.539
Grade of service	E.540–E.599
Definitions	E.600–E.649
Traffic engineering for IP-networks	E.650–E.699
ISDN traffic engineering	E.700–E.749
Mobile network traffic engineering	E.750–E.799
QUALITY OF TELECOMMUNICATION SERVICES: CONCEPTS, MODELS, OBJECTIVES AND DEPENDABILITY PLANNING	
Terms and definitions related to the quality of telecommunication services	E.800–E.809
Models for telecommunication services	E.810–E.844
Objectives for quality of service and related concepts of telecommunication services	E.845–E.859
Use of quality of service objectives for planning of telecommunication networks	E.860–E.879
Field data collection and evaluation on the performance of equipment, networks and services	E.880–E.899

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation E.360.6

QoS routing and related traffic engineering methods – Capacity management methods

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.360.6 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.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

© ITU 2003

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

CONTENTS

Page

1	Scope	1
2	References.....	1
3	Definitions	2
4	Abbreviations.....	2
5	Link capacity design models	2
6	Shortest path selection models	3
7	Multihour network design models	3
7.1	Discrete Event Flow Optimization (DEFO) models	5
7.2	Traffic Load Flow Optimization (TLFO) models	8
7.3	Virtual Trunking Flow Optimization (VTFO) models.....	10
8	Day-to-day load variation design models.....	10
9	Forecast uncertainty/reserve capacity design models.....	11
10	Meshed, sparse, and dynamic-transport design models.....	12
11	Conclusions/recommendations	14
Annex A – Modelling of traffic engineering methods.....		15
A.1	Per-virtual-network vs. per-flow network design.....	15
A.2	Integrated vs. separate voice/ISDN and data network designs.....	16
A.3	Multilink vs. 2-link network design	21
A.4	Single-area flat vs. 2-level hierarchical network design	21
A.5	EDR vs. SDR network design	23
A.6	Dynamic transport routing vs. fixed transport routing network design.....	25

Introduction

In this Recommendation we discuss capacity management principles, as follows:

Link Capacity Design Models. These models find the optimum tradeoff between traffic carried on a shortest network path (perhaps a direct link) versus traffic carried on alternate network paths.

Shortest Path Selection Models. These models enable the determination of shortest paths in order to provide a more efficient and flexible routing plan.

Multihour Network Design Models. Three models are described including:

- i) discrete event flow optimization (DEFO) models;
- ii) traffic load flow optimization (TLFO) models; and
- iii) virtual trunking flow optimization (VTFO) models.

Day-to-day Load Variation Design Models. These models describe techniques for handling day-to-day variations in capacity design.

Forecast Uncertainty/Reserve Capacity Design Models. These models describe the means for accounting for errors in projecting design traffic loads in the capacity design of the network.

See ITU-T Recs E.520 to E.529 and E.731 on dimensioning of TDM networks; E.735 and E.737 on dimensioning of ATM networks; E.733 on dimensioning of SS7 signalling networks and E.734 on dimensioning of IN network resources.

ITU-T Recommendation E.360.6

QoS routing and related traffic engineering methods – Capacity management methods

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):

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.

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 Link capacity design models

As illustrated in Figure 1, link capacity design requires a tradeoff of the traffic load carried on the link and traffic that must route on alternate paths.

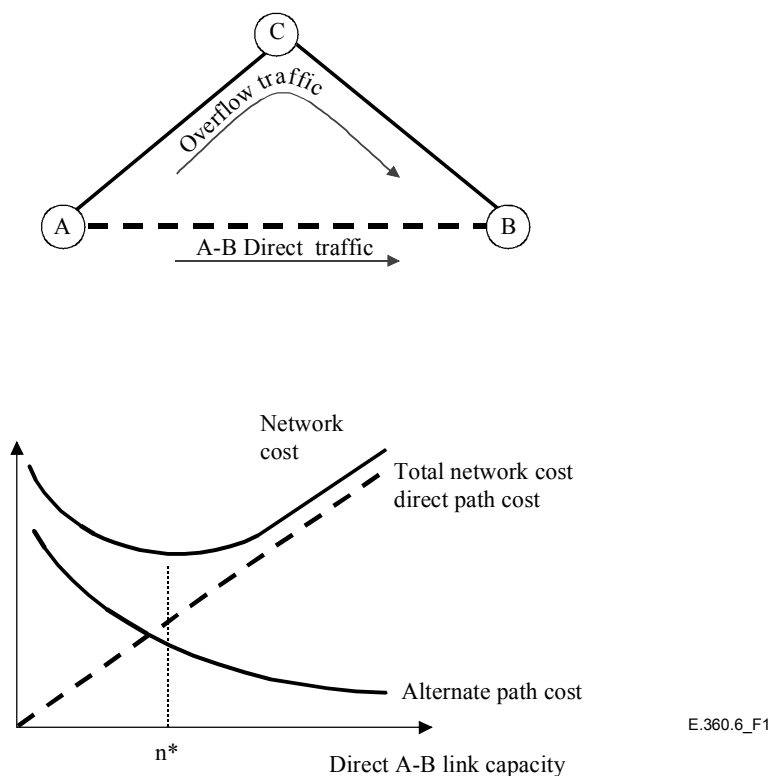


Figure 1/E.360.6 – Tradeoff between direct link capacity and alternate path capacity

High link occupancy implies more efficient capacity utilization, however high occupancy leads to link congestion and the resulting need for some traffic not to be routed on the direct link but on alternate paths. Alternate paths may entail longer, less efficient paths. A good balance can be struck between link capacity design and alternate path utilization. For example, consider Figure 1 which illustrates a network where traffic is offered on link A-B connecting node A and node B.

Some of the traffic can be carried on link A-B, however, when the capacity of link A-B is exceeded, some of the traffic must be carried on alternate paths or be lost. The objective is to determine the direct A-B link capacity and alternate routing path flow such that all the traffic is carried at minimum cost. A simple optimization procedure is used to determine the best proportion of traffic to carry on the direct A-B link and how much traffic to alternate route to other paths in the network. As the direct link capacity is increased, the direct link cost increases while the alternate path cost decreases as more direct capacity is added, because the overflow load decreases and therefore the cost of carrying the overflow load decreases. An optimum, or minimum, cost condition is achieved when the direct A-B link capacity is increased to the point where the cost per incremental unit of bandwidth capacity to carry traffic on the direct link is just equal to the cost per unit of bandwidth

capacity to carry traffic on the alternate network. This is a design principle used in many design models, be they sparse or meshed networks, fixed hierarchical routing networks or dynamic nonhierarchical routing networks.

6 Shortest path selection models

Some routing methods such as hierarchical routing, limits path choices and provides inefficient design. This limits flexibility and reduces efficiency. If we choose paths based on cost, and relax constraints such as a hierarchical network structure, a more efficient network results. Additional benefits can be provided in network design by allowing a more flexible routing plan that is not restricted to hierarchical routes but allows the selection of the shortest nonhierarchical paths. Dijkstra's method [Dij59], for example, is often used for shortest path selection. Figure 2 illustrates the selection of shortest paths between two network nodes, SNDG and BRHM.

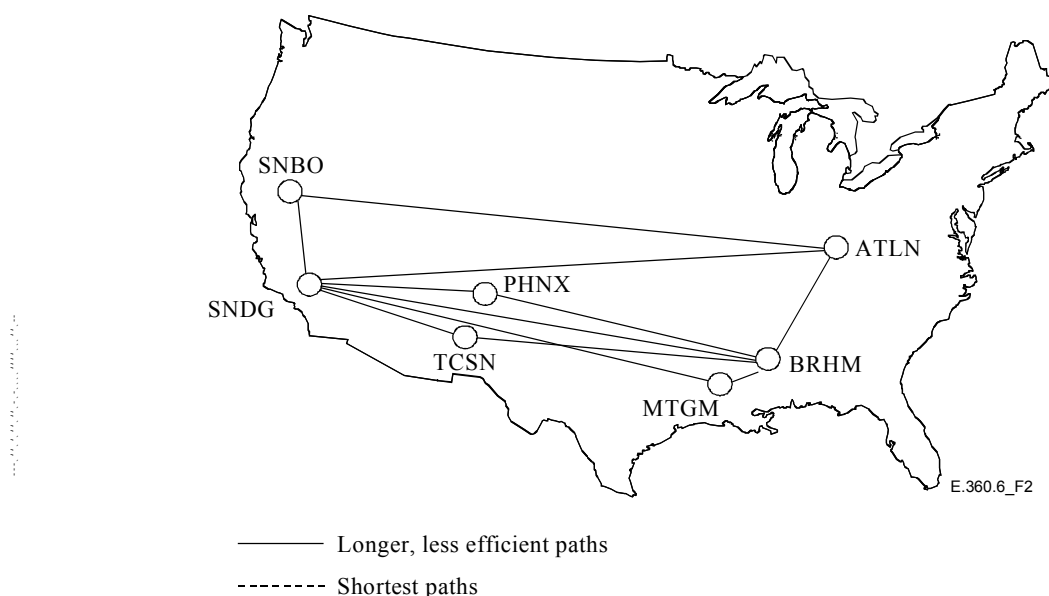
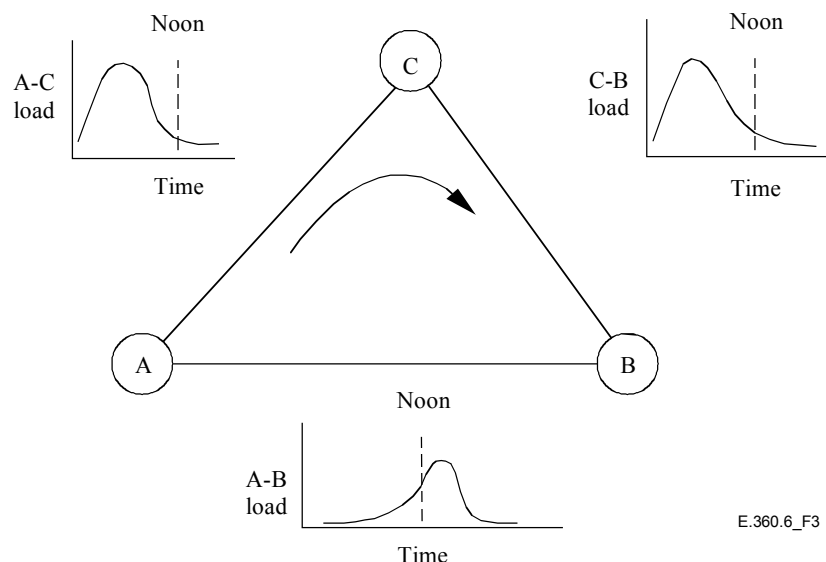


Figure 2/E.360.6 – Shortest path routing

Longer paths, such as SNDG-SNBO-ATLN-BRHM, which might arise through hierarchical path selection, are less efficient than shortest path selection, such as SNDG-PHNX-BRHM, SNDG-TCSN-BRHM, or SNDG-MTGM-BRHM. There are really two components to the shortest path selection savings. One component results from eliminating link splintering. Splintering occurs, for example, when more than one node is required to satisfy a traffic load within a given area, such as a metropolitan area. Multiple links to a distant node could result, thus dividing the load among links which are less efficient than a single large link. A second component of shortest path selection savings arises from path cost. Routing on the least costly, most direct, or shortest paths is often more efficient than routing over longer hierarchical paths.

7 Multihour network design models

Dynamic routing design improves network utilization relative to fixed routing design because fixed routing cannot respond as efficiently to traffic load variations that arise from business/residential phone use, time zones, seasonal variations, and other causes. Dynamic routing design increases network utilization efficiency by varying routing tables in accordance with traffic patterns and designing capacity accordingly. A simple illustration of this principle is shown in Figure 3, where there is afternoon peak load demand between nodes A and B, but a morning peak load demand between nodes A and C and nodes C and B.



E.360.6_F3

Figure 3/E.360.6 – Multihour network design

Here a simple dynamic route design is to provide capacity only between nodes A and C and nodes C and B but no capacity between nodes A and B. Then the A-C and C-B morning peak loads route directly over this capacity in the morning, and the A-B afternoon peak load uses this same capacity by routing this traffic on the A-C-B path in the afternoon. A fixed routing network design provides capacity for the peak period for each node pair and thus provides capacity between nodes A and B, as well as between nodes A and C and nodes C and B.

The effect of multihour network design is illustrated by a national intercity network design model illustrated in Figure 4. Here it is shown that about 20 percent of the network's first cost can be attributed to designing for time-varying loads.

As illustrated in Figure 4, the 17 hourly networks are obtained by using each hourly load, and ignoring the other hourly loads, to size a network that perfectly matches that hour's load. Each hourly network represents the hourly traffic load capacity cost referred to in Table 1/E.360.1. The 17 hourly networks show that three network busy periods are visible: where we see morning, afternoon, and evening busy periods, and the noon-hour drop in load and the early-evening drop as the business day ends and residential calling begins in the evening. The hourly network curve separates the capacity provided in the multihour network design into two components: Below the curve is the capacity needed in each hour to meet the load; above the curve is the capacity that is available but is not needed in that hour. This additional capacity exceeds 20 percent of the total network capacity through all hours of the day, which represents the multihour capacity cost referred to in Table 1/E.360.1. This gap represents the capacity of the network to meet noncoincident loads.

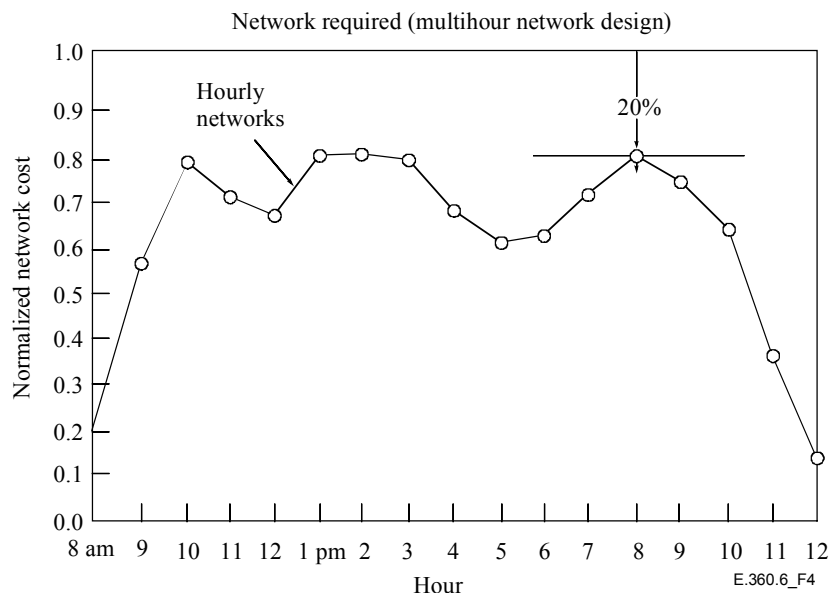


Figure 4/E.360.6 – Hourly versus multihour network design

We now discuss the three types of multihour network design models: discrete event flow optimization models, virtual trunking flow optimization models, and traffic flow optimization models, and illustrate how they are applied to various fixed and dynamic network designs. For each model, we discuss steps that include initialization, routing design, capacity design, and parameter update.

7.1 Discrete Event Flow Optimization (DEFO) models

Discrete event flow optimization (DEFO) models are used for fixed and dynamic traffic network design. These models optimize the routing of discrete event flows, as measured in units of individual connection requests, and the associated link capacities. Figure 5 illustrates steps of the DEFO model.

The event generator converts traffic demands to discrete connection-request events. The discrete event model provides routing logic according to the particular routing method and routes the connection-request events according to the routing table logic. DEFO models use simulation models for path selection and routing table management to route discrete-event demands on the link capacities, and the link capacities are then optimized to meet the required flow. We generate initial link capacity requirements based on the traffic load matrix input to the model. Based on design experience with the model, an initial node-termination capacity is estimated based on a maximum design occupancy in the node busy hour of 0.93, and the total network occupancy (total traffic demand/total link capacity) in the network busy hour is adjusted to fall within the range of 0.84 to 0.89. Network performance is evaluated as an output of the discrete event model, and any needed link capacity adjustments are determined. Capacity is allocated to individual links in accordance with the Kruithof allocation method [Kru37], which distributes link capacity in proportion to the overall demand between nodes.