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**TELEPHONE NETWORK AND ISDN
QUALITY OF SERVICE, NETWORK MANAGEMENT
AND TRAFFIC ENGINEERING**

**METHODS FOR DIMENSIONING
RESOURCES IN SIGNALLING
SYSTEM No. 7 NETWORKS**

ITU-T Recommendation E.733
Superseded by a more recent version

(Previously "CCITT Recommendation")

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FOREWORD

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NOTE

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SUMMARY

This Recommendation describes the methods for dimensioning resources in Signalling System No. 7 networks. It defines the reference traffic to be used for dimensioning and then describes the dimensioning objectives and dimensioning methods for links and nodes in signalling networks. It considers methods for dimensioning signalling links and nodes in Signalling System No. 7 networks. Certain cases (e.g. due to new services) involving segmentation of long messages or mixtures of very long and short messages require further study to give good approximations for signalling link dimensioning purposes.

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Recommendation E.733

METHODS FOR DIMENSIONING RESOURCES IN SIGNALLING SYSTEM No. 7 NETWORKS

(revised in 1996)

1 Scope

This Recommendation considers methods for dimensioning signalling links and nodes in Signalling System No. 7 networks. Certain cases (e.g. due to new services) involving segmentation of long messages or mixtures of very long and short messages require further study to give good approximations for signalling link dimensioning purposes.

2 References

The following Recommendations contain material relevant to this Recommendation: E.500, E.721, E.723, E.492, Q.703, Q.706, Q.709, Q.766 and Q.776.

3 Definitions

In this Recommendation, the following definitions shall be used:

3.1 queueing delay: The queueing delay of a signalling message at the transmit queue of a signalling link is defined as the time from when the last bit of the message is placed in the transmit buffer until the first bit of the message is transmitted and the message is not subsequently retransmitted for level 2 error correction. Note that with this definition, in the case that a message is retransmitted one or more times for level 2 error correction, the queueing delay includes the time it takes to wait for a successful transmission.

3.2 emission time: The emission time of a signalling message on a signalling link is the time it takes to place all the bits of the message onto the transmission media. The emission time is equal to the length of the message (octets) divided by the transmission speed (octets/sec.).

3.3 sojourn time: The sojourn time of a signalling message being sent over a signalling link is defined as the time from when the last bit of the message is placed into the transmit buffer until the last bit of the message is transmitted and the message is not subsequently retransmitted for level 2 error correction (i.e. the sum of queueing delay and emission time). The end-to-end sojourn time of a signalling message going over a path of signalling links and intermediate nodes is the time from when the last bit of the message is placed in the transmit queue of the first signalling link in the path until the last bit of the message is received at the far end of the path and the message is correctly received (i.e. it does not fail the level 2 CRC error check).

3.4 propagation time: The propagation time of a correctly received signalling message over a signalling link is the time from when the first bit of the message is placed on the transmission media until the first bit of the message is placed in the receive buffer at the receiving end of the link.

4 Introduction

This Recommendation provides a methodology for the planning of Signalling System No. 7 networks, which may be used for circuit-related signalling [e.g. to convey Telephone User Part (TUP) and most ISDN User Part (ISUP) messages] and non-circuit-related signalling [e.g. to convey Transaction Capabilities Application Part (TCAP) messages]. Fundamentally different methods are required from those used for planning circuit-switched telephone networks since Signalling System No. 7 is essentially a delay system and the service times are much shorter.

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Clause 5 describes the reference traffic and reference period to be used to dimension the number of signalling links and to ensure that the capacity of network switching elements is not exceeded. The factors for determining a maximum design link utilization, ρ_{max} , are given, which ensure that the end-to-end delay objectives described in Recommendation E.723 are met for the reference connection described therein. Initial values for ρ_{max} being used are described. Methods are then given for determining the number of signalling links required and the switching capacity required.

It is important to note that the efficiency of signalling links should not be the primary consideration when planning signalling networks. The performance of the network under failure and traffic overload has greater significance than when planning circuit-switched telephone networks.

5 Reference traffic

5.1 This clause defines the reference traffic needed to give the basis for dimensioning of Signalling System No. 7 networks. This Recommendation is based on Recommendation E.500 which gives the basis for the measurements needed for the design of circuit-switched networks.

5.2 The reference period in Recommendation E.500 is one hour. In Signalling System No. 7 networks, this is considered too long because the service times and system time constants are expected to be far shorter than in the circuit-switched case. A reference period of shorter than one hour (e.g. five to fifteen minutes) is suggested; the actual value depends on the measured traffic variability as discussed in 5.4.

5.3 The recommended reference traffic is determined in the following way:

The traffic intensity is measured continuously over a day for consecutive traffic reference periods. The highest intensity value for each day is retained.

The reference load over a sliding window of M days is the average of the N highest daily peak intensities over those M days. A provisional value for N is five days. The signalling links should be dimensioned to handle the reference loads that materialize in the network.

[This is based on the philosophy of the Average Daily Peak Hour (ADPH) method recommended in Recommendation E.500.]

5.4 To account for the variability of traffic intensity within the traffic reference period, it is useful to introduce a factor K which multiplies the reference load to determine the load user for signalling link dimensioning. The factor K represents the degree to which the actual traffic intensity is greater than for stationary Poisson traffic.

The factor K must be determined by special studies that take traffic measurements over shorter time intervals to determine the traffic variability within a traffic reference period for the network being considered. Studies have shown that this factor will vary considerably between networks (e.g. between 1.08 and 1.23 for two reported studies), so a single value cannot be recommended for all networks.

One method that has been used to estimate the factor K is as follows:

A sliding window of width w is used with window sizes, w, ranging from 1 second to 100 seconds. For each traffic reference period considered, the average load is computed over the sliding window when it is placed at intervals (0, w) (w, 2w), etc. For each window size, w, the maximum sliding window average load is determined, and the ratio of this maximum sliding window average to the average load over the traffic reference period is determined. This is called the measured peak-to-mean ratio for window size w.

The factor K is determined by comparing the measured peak-to-mean ratios for different window sizes to the corresponding expected peak-to-mean ratios assuming the message arrival process is a stationary Poisson process and a traffic intensity equal to the average load measured over the traffic reference period. The factor K for window size w, K_w , is the measured peak-to-mean ratio divided by the expected Poisson peak-to-mean ratio. The factor K is then the maximum of K_w over the considered window sizes, w. A method for determining the expected Poisson peak-to-mean ratios is now described.

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For a window size w , the peak interval is the interval with the largest average load out of t_{ref}/w intervals, where t_{ref} is the length of the traffic reference period. Therefore, the peak interval is estimated to be the $(1 - w/t_{ref}) \times 100$ percentile of the distribution for the average load over an interval of length w . The average load over an interval of width w is a random variable that is most conveniently described in terms of the random variable N_w , which is the number of message arrivals in a period of length w . If the arrival process is Poisson, N_w has a Poisson distribution with mean and variance wL_{ref}/M , where L_{ref} is the measured average traffic load (octets/sec.) over the traffic reference period and M is the average message length. The average load over an interval of length w can be expressed as the random variable $(M/w)N_w$, which has mean L_{ref} and variance $(M/w)L_{ref}$. When the Poisson random variable N_w is approximated by a normal distribution the Poisson peak-to-mean ratio is estimated by the $(1 - w/t_{ref}) \times 100$ percentile of the normal distribution with unity mean and variance $M/(w L_{ref})$. If the Poisson distribution for N_w is used, the expected Poisson peak-to-mean ratio is $M/(w L_{ref})$ times the $(1 - w/t_{ref}) \times 100$ percentile of value for N_w .

If the length of traffic reference period, t_{ref} , is such that the K value is large (e.g. greater than 1.3), it is recommended that t_{ref} be reduced so the measured loads become more accurate and there is less dependence on the estimation of the K value.

6 Dimensioning objectives

This clause describes the objectives that should be used in dimensioning the links and nodes in Signalling System No. 7 networks.

Signalling networks provide the high availability required (see Recommendation Q.709) by providing diverse extra capacity to handle the load of any failed component. The amount of redundant capacity depends on the signalling network architecture. The nodes and links should be dimensioned to meet objectives specified for failure conditions that fully utilize the redundant capacity.

6.1 Signalling link dimensioning objectives

Signalling links should be dimensioned so that the link utilization, ρ , does not exceed a maximum utilization, ρ_{max} , when there are no failures in the network. To handle failures, the link should be able to support a utilization of $2 \rho_{max}$. The signalling load that determines the link utilization, ρ , is determined as described in clause 5.

6.1.1 Criteria for determining ρ_{max}

ρ_{max} is determined so that link performance criteria are met under the following network conditions:

- normal error condition;
- extreme error condition;
- transient conditions.

In determining ρ_{max} as described below, it is assumed that the signalling processing capacity in the receiving signalling terminal is not exceeded.

The performance criteria given below ensures the Grade of Service (GOS) objectives given in Recommendation E.723 are met, and in addition, provide additional protection against poor performance. The performance objectives given below shall apply for both basic and Preventive Cyclic Retransmission (PCR) error correction (see Recommendation Q.703).

The following notations are used:

- \bar{m} is the mean Message Signal Unit (MSU) length;
- \bar{s} is the mean MSU service time;
- T_L is the signalling link loop propagation delay;
- P_b is the bit error probability;
- P_{SU} is the signal unit error probability;
- ρ is the link utilization;

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- $Q(\rho)$ is the mean transmit buffer queueing delay (not including the emission time) on a signalling link operating at utilization ρ ;
- $Q^{99}(\rho)$ is the 99 percentile of the transmit buffer queueing delay on a signalling link operating at utilization ρ .

6.1.1.1 Normal error condition

The normal error condition on the signalling data link (level 1) is assumed to be random bit errors that occur at the rate of one error in 10^6 bits transmitted. Under this error condition the following should be satisfied:

- $Q(2\rho_{max}) < D_1$ where $D_1 = \text{Max}(40, 0.4T_L)$ ms (provisional value);
- $Q^{99}(2\rho_{max}) < D_1^{99}$ where $D_1^{99} = \text{Max}(200, 2T_L)$ ms (provisional value);
- Error!** $(2\rho_{max}) < L_1$ where $L_1 = 200$ ms/E (provisional value);
- $\frac{dQ^{99}}{d\rho}(2\rho_{max}) < L_1^{99}$ where $L_1^{99} = 1000$ ms/E (provisional value),

where $Q(\rho)$ and $Q^{99}(\rho)$ are the mean and 99% queueing delays on a signalling link operating at utilization ρ . These delays are deduced by mixing all the traffic streams offered to the considered link.

It is important to note that the above limits on delay are for severe load conditions. Under normal conditions the load will be at or below ρ_{max} and delays will be much smaller.

6.1.1.2 Extreme error condition

The extreme error condition is defined to be when the signalling link is operating at an error rate that puts it at the boundary of changeover, which is at a signal unit error probability $P_{SU} = 0.004$ (see Recommendation Q.706). When a link is operating at utilization $2\rho_{max}$ with PCR, the link will not be sending Fill-In Signal Units (FISUs) when the error rate is high, and therefore all signal units will be new or retransmitted message signal units (MSUs). As a result, the MSU error probability, P_m , will equal P_{SU} . For basic error correction, FISUs will be present and the bit error probability, P_b , and the average signal unit error probability, P_{SU} , are related by:

Error!

where

Error!

Thus, for the extreme error condition:

$$P_m = 0.004 [\rho_{eff} + (1 - \rho_{eff})m/6]$$

Under the above defined extreme error condition, the following should be satisfied:

- $Q(2\rho_{max}) < D_2$ where $D_2 = \text{Max}(60, 0.6T_L)$ ms (provisional value);
- $Q^{99}(2\rho_{max}) < D_2^{99}$ where $D_2^{99} = \text{Max}(300, 3T_L)$ ms (provisional value);
- Error!** $(2\rho_{max}) < L_2$ where $L_2 = 300$ ms/E (provisional value);
- Error!** $(2\rho_{max}) < L_2^{99}$ where $L_2^{99} = 1500$ ms/E (provisional value).

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6.1.1.3 Transient conditions

When a high error rate or signalling link changeover occurs, a transient results in signalling link buffers.

ρ_{max} should be chosen so that when these transients occur, the mean transient queueing delay on working links should be less than $D_3 = 500$ ms (provisional value) when all links are operating at ρ_{max} prior to the high error rate condition or signalling link changeover.

6.1.2 Models used to determine queueing delays

6.1.2.1 Conditions for using M/G/1 models

To evaluate $Q(\cdot)$ and $Q^{99}(\cdot)$ to apply the above criterion, a model or simulation results must be used. **Error!**(\cdot) and **Error!**(\cdot) can be evaluated from $Q(\cdot)$ and $Q^{99}(\cdot)$ using graphical methods.

M/G/1 models are available in Recommendation Q.706 for both basic and PCR error correction. These models assume that the message arrival process is Poisson. In actual networks this assumption is not precisely met, but the model is still an acceptable approximation when the following conditions are met:

- 1) A Poisson call arrival process should be a good approximation to the actual original call arrival process.
- 2) The time separation between messages in the same direction associated with the same call should be greater than 1 second for most calls. This is needed in order for the known signalling message correlation to not significantly alter the queueing behaviour from the M/G/1 model.
- 3) The STP processing does not significantly distort message interarrival times (i.e. does not cause significant batching or smoothing of messages).

When signalling messages traverse several upstream successive links and there is a mixture of long and short messages on those links, the M/G/1 model may not hold on the signalling link being considered when that link has little or no fresh arrivals (e.g. this may occur at gateway STPs). This case requires further study.

6.1.2.2 Segmentation of long messages

When segmentation of long messages takes place to transport such messages over an SS No. 7 network, the segments of a long message will have correlated interarrival times as they flow through the signalling network. Therefore, the message segments cannot be assumed to be independent arrivals, and thus the Q.706 M/G/1 models may not be accurate. As the segments of a long message flow through a signalling network, the interarrival times between segments become larger due to other messages arriving and coming in between segments. If the separation between segments is large enough, an M/G/1 model in which all Message Signal Units (MSUs) are assumed to have Poisson arrivals will be a good approximation. This approximation is identified as Model 1. On the other hand, if the MSUs from a segmented message stay very close together, an M/G/1 model in which the segmented message is considered as a batch of MSUs (one long message) would be a good approximation. This approximation is identified as Model 2.

Simulation studies have shown that Models 1 and 2 can be used to determine lower and upper bounds for queueing delays and end-to-end sojourn times when Conditions 1) to 3) above are met.

Consider queueing delays for MSUs of non-segmented messages and the first MSU of segmented messages. For signalling links for which all the segmented traffic is being carried on a signalling link for the first time (so the time separation between segments from a long message are small enough that there is negligible probability that other MSUs will arrive in between segments), the assumptions of Model 2 are met and so it is a good approximation. For signalling links for which all the segmented traffic has gone through at least one previous signalling link, simulation studies have shown that Model 1 is a good approximation when link utilizations are somewhat less than 0.6. For larger utilizations the queueing delays lie between Model 1 and Model 2, with neither being a close approximation.

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Simulation studies have also shown Models 1 and 2 can be used to provide lower and upper bounds on segmented message end-to-end sojourn times. The Model 1 lower bound is determined by computing the sojourn time of the first segment of the long message using queueing delays from Model 1 (Model 2 can be used for the first link if it carries only first offered segmented messages) and then adding to that sojourn time the emission time of each subsequent segment of the long message. The Model 2 upper bound is determined by treating the long message as a single message and computing its end-to-end sojourn time using queueing delays from Model 2. Neither of these bounds gives a good approximation, except at low link utilizations (less than 0.2 for all links) when the Model 1 bound gives a close approximation.

6.1.3 Choosing between basic and PCR error correction

The choice between basic and PCR should be based on the largest loop propagation delay T_L expected in the network. ρ_{max} is then determined to meet the criteria in 6.1.1.1, 6.1.1.2 and 6.1.1.3. The choice between basic and PCR should be for the error correction method that gives the largest ρ_{max} .

6.2 Node dimensioning

Node dimensioning parameters recommended in this subclause are from the point of view of the network provider rather than the network element manufacturer.

Delay and congestion are the most important criteria for node dimensioning. These criteria should be applied considering evolution of the signalling network from the point of view of handling increasing traffic levels and the accepted traffic characteristics. Traffic characteristics are modelled by the message arrival processes and message length distributions. In other words, it is not just the forecasted amount of traffic which dictates the node dimensioning, but also the type of services deployed are important.

Other factors to be considered in node dimensioning are reliability, security and survivability considerations. For example, given certain amount of forecasted expansion of a signalling network load, there are several approaches to provision nodes for increased load as follows:

- one could increase the capacity of existing nodes;
- one could add additional nodes of larger capacity;
- one could reduce the number of nodes and add even larger capacity at remaining nodes;
- one could plan for a large number of smaller nodes.

The last option, though possibly more expensive, is more secure, reliable and survivable. It is more reliable and secure because of diversification of nodes, i.e. failure of a single node affects a lesser amount of traffic. It is more survivable because in the event of natural or man-made disasters the probability of larger amounts of traffic being affected is less. Obviously, quantification of such factors is not an easy task. These factors should be taken into account in node dimensioning by the network planners depending on specific circumstances and individual network requirements.

Also, network topology considerations have an effect on node dimensioning. For example, duplication of some signalling points, such as data bases, may have an effect.

Another complexity factor in this problem is that in a future intelligent network environment there will be a variety of nodes in the signalling network with varying specialized functions. For example, all or a subset of the following types of nodes could be present in future Signalling System No. 7 networks:

- 1) simple exchanges;
- 2) simple Signal Transfer Points (STPs);
- 3) simple data base nodes;
- 4) nodes with both exchange and STP functions;
- 5) nodes with both data base and STP functions (e.g. co-location of global title translation data bases and STPs);
- 6) special purpose nodes (e.g. announcement nodes);
- 7) nodes with combinations of the above functions.

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Obviously, covering all these combinations with a single set of criteria is not practical. It seems that the most practical method of approaching this problem is to define the common dimensioning criteria when applied to well known types of signalling points. We leave the more specific criteria for further study when better understanding of specific functions are available.

Common dimensioning criteria for signalling points are as follows:

6.2.1 Capacity

The signalling capacity of a switch depends on the number of signalling relations and the traffic volume of call related and non-call related signalling. For call related signalling, the notion of signalling capacity is not easily separable from the capacity of the exchange in terms of the number of circuits. What could be recommended from the signalling point of view is that the exchange must have enough signalling capacity so that when working at maximum call volume, it should be able to support the signalling process and support enough links to support the signalling messages and network architecture.

For STPs, the capacity could be defined as the number of MSUs that can be switched in unit time without causing processor congestion or undue cross-office delays. Also, it should be able to handle enough links to support the network architecture and carry the traffic load.

For Signalling Connection Control Part (SCCP) relay points, the capacity could be defined as the number of MSUs that can be relayed in unit time without causing processor congestion or undue cross-office delays. Also, it should be able to handle enough links to carry the traffic.

For databases, the capacity could be defined as the number of queries that could be processed in unit time without causing processor congestion or undue cross-office delays. Naturally, this capacity is closely related to the type of application. Also, it should be able to handle enough links to support the network architecture and carry the traffic load.

6.2.2 Cross-office signalling delay

For exchanges, this is the time interval between the time some information is received by the Signalling System No. 7 subsystem from the user application (e.g. call processing) and the time the last bit of a corresponding message is delivered to Message Transfer Part (MTP) level 1 in that office. For POTS calls this delay includes processing times for ISUP (or TUP) and MTP processing delay. For messages bound to or from databases, this delay includes processing times for TCAP, SCCP and MTP.

For STPs, this is the time interval between the moment the last bit of the incoming MSU is put in the receive buffer of the incoming link and the moment the last bit of the MSU is transmitted on the outgoing link.

For SCCP relay points, this is the time interval between the moment the last bit of the incoming MSU is put in the receive buffer of the incoming link and the moment the last bit of the response MSU is transmitted on the outgoing link.

For databases, this is the time interval between the moment the last bit of the incoming MSU is put in the receive buffer of the incoming link and the moment the last bit of the response MSU is transmitted on the outgoing link minus the time needed for the application processing. This consists of MTP, SCCP and TCAP processing delays in both directions.

Values for cross-office signalling delays appear in Recommendations Q.706, Q.766 and Q.776.

6.2.3 Signalling links

The number of signalling links a signalling point can accommodate is an important parameter for network planning. This parameter is especially important for STPs.

6.2.4 Availability

The availability of a signalling point is defined as the fraction of time that the signalling point is in full working condition.

6.3 Value for ρ_{max}

Presently the values used for ρ_{max} vary from 0.2 to 0.4.

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7 Signalling link dimensioning methods

7.1 Load calculation

Recommendation E.713 gives the procedure to evaluate the signalling load between two nodes signalling point and/or signal transfer point (SP and/or STP) over a reference period. Dividing these quantities by the reference period length yields under no failure conditions:

- L' is the total load in bit/s in one direction;
- L'' is the total load in bit/s in the opposite direction.

For dimensioning purposes, the significant parameter is the largest of the two. This is because a signalling link is actually a pair of unidirectional channels.

- $L = \text{Max}(L', L'')$.

7.2 Single link capacity

The capacity, C , of a single link is defined to be the maximum bit rate that a signalling link can carry with no failures in the network. It is calculated as:

$$C = S_L \rho_{max}$$

where:

- S_L is the link speed in bit/s; and
- ρ_{max} is defined in clause 5.

7.3 Link set capacity

In Signalling System No. 7, load sharing over link sets is done using the 4-bit Signalling Link Selection (SLS) field, and due to modularity effects this procedure does not always allow a completely balanced load distribution over links within a link set. As a result, not all of the signalling link capacity is available for use. Consequently, capacity of a link set is the maximum signalling load that can be shared without exceeding the capacity of any single link.

The number of SLS bits that are available for load sharing over a link set depends on network architecture.

Table 1 provides the link set capacity C_m , as a function of the single link capacity, C , the number of links in a link set m , and the number of SLS bits available for load sharing:

TABLE 1/E.733

Number of links m	Link set capacity (C_m)	
	4 SLS bits used	3 SLS bits used
1	C	C
2	$2C$	$2C$
3	$(8/3)C$	$(8/3)C$
4	$4C$	$4C$
5	$4C$	$4C$
6	$(16/3)C$	$4C$
7	$(16/3)C$	$4C$
8	$8C$	$8C$

NOTE – The link set capacity in Table 1 is the maximum allowed load when there are no failures in the network.

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In determining the link set capacity given in Table 1, it has been assumed that signalling traffic load between every signalling point pair is uniformly distributed over the SLS codes (in terms of both traffic intensity and message length distribution). If this is not the case, a more detailed analysis is required that takes into account the different traffic characteristics of different SLS codes.

7.4 Dimensioning procedure

Given the calculated load, L (7.1), and the single link capacity, C (7.2), the number of links, m , required in the link set is obtained from Table 1, assuring that $L \leq C_m$.

8 Recommendation history

Recommendation E.733 – First issued in 1992; revised in 1996.

Annex A

Alphabetical list of abbreviations used in this Recommendation

(This annex forms an integral part of this Recommendation)

ADPH	Average Daily Peak Hour
FISU	Fill-In Signal Unit
GOS	Grade of Service
ISUP	ISDN User Part
MSU	Message Signal Unit
MTP	Message Transfer Part
PCR	Preventive Cyclic Retransmission
SCCP	Signalling Connection Control Part
SLS	Signalling Link Selection
SP	Signalling Point
STP	Signal Transfer Point
TCAP	Transaction Capabilities Application Part
TUP	Telephone User Part