TRAFFIC CONSIDERATIONS OF NEW GENERATION OF TELEPHONE SET

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ABSTRACT
The signaling features of the present telephone set impose significant traffic burdens upon the control of the switching equipment. The recent trends toward digital switching and transmission illuminate the deficiencies of the present set and invite a new design. Dramatic reductions in quantities of control equipment and improvements in administration will accompany various features described in the main text.

BACKGROUND
The present telephone set design has existed with little change in acoustical principle for almost 100 years and some of its signaling features have been in use for 75 or more years. The acoustical characteristics are of minor concern here, but the signaling methods impose various burdens of traffic-dependent nature upon the control. Some of these will be discussed below and from these considerations a few of the more significant requirements for a new generation of telephone set will be derived. The specifications for such a set are being discussed in the United States. This paper represents the author's views of the form and in no way represents a commitment of effort or of final product.

THE EXISTING TELEPHONE SET
The signaling protocols of the present telephone set are a surprisingly complex arrangement of signal elements conveyed in and out of band by two and four wire, compelled and non-compelled, digital and digital-in-analog form, not to mention by individual power levels with range over several orders of magnitude. Additionally, the present set requires a man-machine-man dialog so that a significant portion of the design effort of the switching control (perhaps 50%) is devoted to what the human caller may do rather than what he or she is supposed to do. In short, much of the control logic must be designed for possibilities of human behavior, whereas the switching matrix, trunking and other traffic sensitive elements can be designed for the probabilities of the user actions.

The man-machine-man relations represent traffic loads in two ways, (a) the man-machine interface when originating a call, and (b) the machine-man communications when receiving a call.

The traffic problem at the calling end actually is in three parts, (a) the determination of delay when receiving a register or receiver (dial tone delay), (b) setting the interdigital time outs and (c) setting the register time out interval for very slow or incomplete dialing. The holding time distribution which describes the entire call actually is the sum of several distributions which relate to these and other segments of the call.

The overall holding time distribution of the telephone calls follows or tends to follow the well-known negative exponential distribution (NED) which is represented in Fig. 1. After dial tone, the next part of a call involves entering the called number into some form of register or receiver. There is a probability distribution of interdigital entry times, i.e., the interval which separates the end of one digit and the beginning of the next. This distribution depends somewhat upon the pair of digits under investigation, for example, in the United States when entering a 7-digit number there tends to be a longer delay between the third and fourth digits than between any other pair. For the purposes here, the precise form of the distribution is not important, except that part of these variations are attributes of human behavior in general, and part comes from the characteristics of the dial. This mechanism in effect converts the directory number from base 10 to base one and creates one interruption of line current for each denumerable count of the number dialed (i.e., the number four is represented by four interruptions.) As the telephone numbers of most national networks employ six or more digits, the number of interruptions for a seven digit number can range from seven (1111111) to 70 for (0000000). The time of dialing will vary between about six and approximately 15 seconds because of this alone, but tends to exhibit a mean of approximately 10 seconds. It can be seen that any time out may cut off some valid dialing actions and the administrative problem becomes that of deciding what proportion of customers can be rejected from the system because of slow progress. A suitable time out interval can be quite long, for example, if the register holding time distribution were NED with mean of 10, and if the objective is to reject no more than say 1% of the callers, then the minimum time out must be about 4.6 times the average holding time, or 46 seconds.

Fig. 1 Sketch depicting the well-known negative exponential distribution.

The interdigital distributions become more important when open numbering plans are employed. In the United States the called number can be one, three, four, seven, 10, 11 or 13 digits long if made from a regular telephone or one additional digit in each of these cases if made from a PABX. When a pure register system interfaces directly with the caller, interdigital (actually last digit) time out is the only workable way for the control to decide that all digits have been received. 1/ The problem is solvable directly if a special end-of instruction (EOI) character can be sent, but the dial offers no capability for introducing such a character.

Generally similar comments apply for telephones equipped with keysets, except that (a) the form of all characters are the same, (b) the average holding time tends to be less so that fewer registers are needed for the same dial tone delay, and (c) a shorter overall time-out sometimes can be imposed. Also, the systems plan allows for several buttons whose function has not yet been defined. One of these could become the EOI symbol.

1/ The problem does not exist in most step-by-step systems because the last digit operates the last switch.
The other traffic dependent characteristics of existing telephones is found in the ringing or alerting cycle. As shown in Fig. 2, all telephones which are served by a given equipment and which are being rung at the same time are connected to the ringing source in such a way that the audible-silent pattern causes about 1/Nth of these telephones to be rung simultaneously where N is a small integer. Two traffic dependent problems here are (a) the determination of the maximum number of telephones that may be in the audible mode at the same time, (value of N) and (b) the maximum length of time that an unanswered telephone will be allowed to ring if the calling party chooses not to abandon the call. Item (a) relates to the loading placed upon the ringing generator, while (b) pertains to the number of ringing ports that must be provided somewhere in the matrix. The present system can utilize one of the finite resources of the switch for exorbitant periods, yet the ringing time-out must be long enough to allow a slow answer which results from legitimate causes.

All of these problems can be reduced enormously in scope and effect by the technology of today. A new generation of telephone set is needed badly if the new techniques of digital switching and digital transmission in local loops are not to be compromised. Such a set is described next.

**A NEW TELEPHONE SET**

First, for the purposes here, it is assumed that this new set will be electronic in nature and will interface directly with digital transmission media. The set probably will be powered by local batteries recharged from the commercial supply. It also is assumed that the new telephone will talk. None of these four characteristics will be developed further because it is the logical properties which are of concern here.

As shown in Fig. 3, the logic ordinarily would be inert except for a small section which detects the incoming ringing (ringing) signal. To make a call, the caller lifts the handset (or performs a similar function) whereupon the entire logic is energized and the set displays its directory number on the set itself. The set returns acoustical dial tone to the caller accompanied (perhaps) by a winking lamp display. The caller enters the called number including prefixes when required.

Upon entry of the first character, the display blanks, and with this and each new entry the digits of the called number march onto the display as with a pocket calculator. When the caller is satisfied with the number, he or she presses the EOI button (some suggest this be called the GO button) and the set then hails the switching control.

The control then asks for a dump which includes (a) the directory number of the called telephone, (b) the directory (or billing) number of the calling telephone, (c) the classes of service of the calling telephone when making a call, and (d) the location coordinates of the calling telephone. About 50 digits or about 400 bits of information will suffice for this transmission. If digital carrier transmission techniques are employed, only about six or seven milli-seconds would be needed to complete the entire transaction.

Before proceeding with other set-up steps, the impact of this much will be investigated. First, except for intentional mis-keying, almost all follies of the caller are kept from the switch control by the barrier of the set. Only a deliberate act (as identified by the EOI signal) will present a number to the control, so no preliminary abandonments are imposed upon the exchange. The holding time of the register at the switch is reduced from approximately NED with mean of 8-10 seconds to almost constant timing rate of about 140 calls/second (at 100% occupancy) or about 100 per second when loaded to about 70%. A single register (with backup) would provide enough capability to serve an exchange of over 100,000 lines. This is in sharp contrast to present dimensioning requirements where registers are about one percent of the number of lines.

Returning now to the call set up, the control establishes the connection through the network, and upon being attached to the called line interrogates the called set for its directory number, its called classes of service, and its location coordinates. The switching control verifies that the called directory number is the same as that desired (or initiates a recovery procedure if not), compares the classes of service of the calling and called telephones to see if this particular call is allowed (purging if not). If billing is required, the control will calculate the billing rate by the distance between the location coordi-
nates. Assuming that all is satisfactory, the control
transmits a ringing-start signal forward and a ring-back
starting signal backward.

The called set then generates a ringing sequence by using
its own local power, and the calling set generates ring­
back tone for its user. (Similarly, busy tones are gener­
ated within the calling set.) This single feature of gen­
erating ringing power at the set relieves the exchange of
all concerns about attaching high voltage ringing poten­
tials to the line and of providing ringing ports. Com­
mands for recorded announcements would be generated in the
network as and where required. It appears to be quite
feasible that the encoded form of 10-12 common recordings
could be stored within the set itself. If this proves to
be so, then a forced release signal would accompany the
recording command in the backward direction causing the
calling set to release the line forward. The set then
would be in the barrier state and would not react with the
control again unless an incoming call is received or un­
less the EOI signal is entered for an outgoing call.

If arranged properly, these and other features allow some
of the protocols of common channel signaling to interface
directly with the telephone set itself. Then and only
then does the power of such concepts as traveling class
marks begin to emerge. Indeed, by storing the classes of
service within the set itself, each extension of the same
line can be accorded different calling privileges if the
customer desires. Also the from-to aspects of calls, with
information about the ultimate disposition (completed,
blocked, etc.) will allow very detailed traffic studies to
assist in the administration of both the local exchange
and the national network.

Numerous other advantages accrue from this new set which
are not related to traffic. As a single example, the
problem of tracing nuisance calls would be solved forever,
because each set contains its own location coordinates and
telephone number. The problems of apprehension and pros­
ection remain, but at least the location of the culprit
could be identified readily.

Several very advanced features relate to the concept of
location coordinates, both the nature and the source
merit additional comments.

LOCATION COORDINATES

In the United States a large amount of traffic data are
gathered to support the manner in which toll revenues are
to be divided between the various telephone companies.
For this and other reasons, it would be helpful if the
location of each telephone set were known within say 100
meters. At least two methods exist for satisfying this
need.

Toll bills are calculated in the United States on a time -
distance and type-of-service basis. The distance is de­
termined by a national coordinate scheme which employs two
4-digit numbers to locate the central office with a resol­
tution of about 500 meters. By adding one digit to each of
these two numbers, the error can be reduced to about 50
meters or to an area of about 1/4th of a city block. Al­
ternatively, the United States Postal Service is planning
to expand its 5-digit Zone Improvement Plan (ZIP) codes by
four additional digits (9 in all) so that each code will
identify uniquely an area the size of a city block. Al­
though the details still are evolving, the intent is that
mail will be routed by means of ZIP code to the carrier
who actually makes the final delivery. Although the ZIP
code areas will not be uniform in size and shape, once
established, the center of each can be located uniquely by
longitude and latitude, or by the coordinate system dis­
cussed above. In either case, the billing switch can cal­
culate the great circle distance between the calling and
called telephones. This will permit very precise billing
plans, and will end the never-ending complaints of sub­
scribers residing across the street from each other - but
served by different exchanges - who must pay a toll charge
based upon the great circle distance between the central
offices.

CONCLUDING REMARKS

Ten years ago such a set was unthinkable, five years ago
it was daring in concept, today the need is real and the

technology is available. The logic described here is nei­
ther complex nor expensive and involves mostly non-vola­
tile memory that will survive total power failures (such
as when changing batteries in the set). There is no sug­
gestion that existing sets be replaced with one as descri­
based here. Rather this new telephone will merge neatly
with the increasing use of digital switches and transmis­
sion and will simplify the software of the switch signif­
icantly. It is believable that with the economies of
large production runs the set described here actually
could be cheaper than the present items.

Much work remains to complete the specifications of this
device, but the obvious operational and service advan­
tages urge that the work proceed expeditiously.

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