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Temporary Call-back Telephone Number Service

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***Abstract*—Conventional temporary telephone number (TTN) service provides a secondary telephone number to a service subscriber. The subscribers can protect privacy by sharing their TTNs without revealing their private numbers. However, TTN service is rarely provided because it requires a large amount of temporary telephone numbers. In this paper, we present a restricted form of TTN service – temporary call-back telephone number (TCN) service – to reduce the amount of telephone numbers needed. A TCN is assigned only for the communications between a subscriber and the correspondent parties specified by the subscriber. Other users, except for the specified correspondent parties, cannot reach the subscriber through the assigned TCN. A TCN assignment can be specified by a telephone number mapping record that consists of a subscriber's number, a TCN, and a correspondent party's number. A TCN can be assigned to more than one subscriber, as long as the subscribers' specified correspondent parties are different. Analytic models using Markov chains have been developed to show that the TCN service significantly reduces the amount of temporary numbers required. The TCN service can be implemented using the Intelligent Network (IN) service architecture as a value-added service. TCN Subscribers can initiate calls to and receive calls from the specified correspondent parties without revealing their private telephone numbers. However, the TCN service is not a replacement of the conventional TTN service because only the specified correspondent parties can reach the subscriber by the assigned TCN.**

Keywords- temporary telephone number, call-back, telephone number mapping

I. INTRODUCTION

Conventional temporary telephone number (TTN) service provides a subscriber a secondary telephone number [1]-[3]. The subscriber can be reached by the assigned TTN, as well as his or her private telephone number. The subscriber can protect privacy by sharing or publishing a TTN for public purpose without revealing his or her private number. A TTN is usually not permanently assigned, but rather used for a relatively short period of time and then disposed by the subscriber. When a user gives up a telephone number (e.g., by terminating the telephone service), the reclaimed number is placed in an aging pool for a certain time period before it can be re-assigned to another user. In this aging period, calls to the reclaimed number are routed to a voice announcer informing the callers that the number has been disconnected. When a reclaimed number is re-assigned to another user, this aging process reduces the chance that the new owner receives calls that are intended for the old owner. The aging period is 90 days for a residential number and is 365 days for a business number. This practice of aging period should also be applied to the disposed TTNs.

To provide TTN service, an operator needs to reserve a pool of temporary telephone numbers. Since the TTN assigned to each subscriber must be unique, TTN service requires at least as many temporary numbers as the number of the subscribers. Moreover, when a temporary number is disposed by a subscriber, the disposed number becomes an aging number for at least 90 days before it can be re-assigned to another user. This aging process further increases the size of the number pool reserved for TTN service. Since telephone numbers are resources that need to be conservatively used, very few operators provides temporary number service.

In this paper, we present a restricted form of TTN service – a temporary call-back telephone number (TCN) service. A TCN assigned to a subscriber is not a secondary telephone number, but rather a call-back number for the correspondent parties specified by the subscriber, i.e., only the specified correspondent parties can reach the subscriber by dialing this call-back number; other users cannot. Our approach requires a much smaller size of reserved number pool than TTN service because a TCN can be assigned to more than one subscriber, as long as their specified correspondent parties are different. When a subscriber initiates phone calls to the specified correspondent parties, the calling party number of the call setup message (i.e., SS7 Initial Address Message [4]) will be replaced by the assigned TCN. In this way, the subscriber can communicate with the specified correspondent parties without revealing his or her private telephone number. This service would be attractive to users concerned with their personal data privacy. For example, an on-line shopper can use a TCN to contact an on-line merchant, and depose the TCN after the trade transaction is complete. The TCN service presented in this paper can be implemented in the Public Switched Telephone Network (PSTN) as an Intelligent Network (IN) value-added service [4].

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II. TEMPORARY CALL-BACK TELEPHONE NUMBER SERVICE

For the temporary call-back telephone number (TCN) service, a TCN is assigned for the communications between a subscriber and the correspondent parities specified by the subscriber. This association of a subscriber, a TCN and a subscriber-specified correspondent party is stored in a telephone number mapping table, as shown in Table I. Each record (row) in the mapping table indicates the TCN used for the communications between the subscriber and the correspondent party specified in the record. For example, the first two records in the mapping table of Table I indicate that TCN 0900-000 is assigned to the subscriber whose number is 0955-111 for communications with the correspondent parties whose numbers are 0922-222 and 0922-333. Note that a TCN can be assigned to different subscribers as long as the subscriber-specified correspondent parties are different. For example, the record in row 3 indicates that the same TCN (0900-000) is assigned to subscriber 0955-999 for communications with correspondent party 0922-444. However, the same TCN cannot be assigned to different subscribers if the subscriber-specified correspondent parties are the same. As a result, the record in row 4 indicates that TCN 0900-001 is assigned to subscriber 0955-111 for communications with correspondent party 0922-444; in this case, TCN 0900-000 cannot be assigned because it has been assigned to subscriber 0955-999 for communications with the same correspondent party, 0922-444. Note that all the temporary call-back numbers have the same three-digit prefix, 900. This three-digit prefix will be used to trigger TCN service.

TABLE I. TELEPHONE NUMBER MAPPING TABLE

	Subscriber's telephone number	Temporary call-back number	Correspondent's telephone number
1	0955-111	0900-000	0922-222
2	0955-111	0900-000	0922-333
3	0955-999	0900-000	0922-444
4	0955-111	0900-001	0922-444
5	0955-999	0900-001	0922-222

The proposed TCN service can be implemented in PSTN using Intelligent Network architecture. The system architecture is depicted in Figure 1. To provide TCN service, Service Switching Points (SSPs; Figure 1 (a) and (d)) need to query a TCN Service Control Point (SCP; Figure 1 (b)) when TCN service is triggered. The TCN SCP performs the service logic based on the mapping records stored in the telephone number mapping table (Figure 1 (c)). In addition, a TCN Service Center (SC; Figure 1 (e)) receives TCN service requests and maintains the telephone number mapping table.

Before a subscriber receives the TCN service, mapping records must be created for the subscriber and the specified correspondent parties. For example, User A (Figure 1 (f)) can create a mapping record for communications with User B (Figure 1 (g)) in either one of the following ways.reproduced from your originals. Line drawings, graphs, programs, tables, and mathematical notations will be reworked before publication.

1. User A dials to the TCN SC (Figure 1 (e)) equipped with an IVR (Interactive Voice Response), follows the IVR's instructions, and inputs User B's number. The TCN SC searches for an unused TCN and creates a mapping record (e.g., row 1 of Table 1).
2. User A dials a service code and User B's number. A service code can create a mapping record only, while another service code can create a mapping record and dial to the correspondent party. For example, *922-222 creates a mapping record for communications with User B, and #922-222 creates a mapping record and initiates a call to User B.
3. User A connects to the TTN SC through web interface to create a mapping record (e.g., row 1 of Table 1).

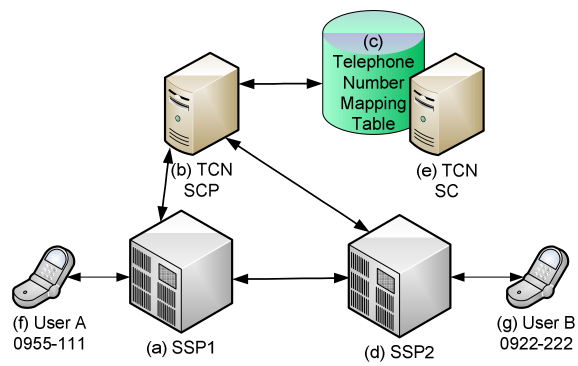

Figure 1. The system architecture for TCN service.

In similar ways, User A can delete a mapping record to terminate TCN service for communications with User B. Alternatively, User A can specify the valid period of the TCN number at the subscription, and therefore the TCN is automatically cancelled when the valid period expires.

As long as, a valid mapping record exits, the TCN service is provided in the same way as any IN value-added service. When User A initiates a phone call to User B, the service is provided in the following steps.

1. User A (with phone number 0955-111) calls User B by dialing 0922-222. This call is set up to SSP 1 (Figure 1 (a)).
2. Since User A is a TCN subscriber, TCN service is triggered, and SSP 1 queries the TCN SCP (Figure 1 (b)) with the telephone numbers of the calling party and the called party, i.e., User A and User B's numbers.
3. The TCN SCP checks if a matched mapping record exists for the calling and the called parties in the corresponding data fields. Suppose that the entry is found (e.g., row 1 of Table 1), the TCN SCP instructs SSP 1 to replace the calling party's number with the TCN (0955-000) in the matched record. On the other hand, if no matched record is found, the TCN SCP instructs SSP 1 to route the call as a normal call, i.e., the calling party's number is not changed.
4. When instructed, SSP 1 replaces the calling party's

number and routes the call to User B (Figure 1 (g)). User B receives the call with the caller ID indicating the TCN (0955-000), not the User A's number.

After User B receives a call from User A, User B may call back to User A by dialing the TCN, i.e., the caller ID received. The service is provided in the following steps.

1. User B (Figure 1 (g)) dials the TCN, 0900-000. The call is set up to SSP 2 (Figure 1 (d)).
2. Since the dialed TCN has a 900 prefix, TCN service is triggered, and SSP 2 queries the TCN SCP (Figure 1 (b)) with the calling party's number (0922-222) and the TCN.
3. The TCN SCP checks if a matched mapping record exists for the TCN and the calling party in the corresponding data fields. Suppose that the entry is found (e.g., row 1 of Table 1), the TCN SCP instructs SSP 2 to route the call to the subscriber's number (i.e., User A's number, 0955-111) in the mapping record. If no matched record is found, the TCN SCP instructs SSP 2 to route the call to an IVR, which will inform the calling party that the call cannot be set up.
4. SSP 2 routes to the call as instructed by the TCN SCP.

One of the design issues is the management of the telephone number mapping table, in particular, how to select a TCN for a subscriber's request. When a subscriber requests a TCN for the communications with a correspondent party, the TCN SC needs to find an unused TCN, i.e., a TCN that has not be assigned for the communications with the specified correspondent party and other subscribers. If no unused TCN can be found, the service request cannot be fulfilled. Therefore, a limitation of the TCN service is that the number of subscribers who specified the same correspondent party cannot be larger than the total number of TCNs.

III. Analytic Models and Results

To provide TTN or TCN services, a PSTN operator needs to reserve a pool of telephone numbers. Since telephone numbers are valuable resources, operators will not reserve more numbers than is necessary. The size of the number pool is typically selected such that 99.9% of the TTN or TCN requests can be fulfilled. We need to estimate the sizes of the number pools for TTN service and TCN service

A. Conventional TTN Service

Consider the life cycle of a TTN in service. A TTN becomes active (in use) when it is assigned to a subscriber. The subscriber uses the TTN for a period of time, and then releases the number. A released number is put in an aging pool for an aging period of 90 days, before it can be re-assigned to other users. To estimate the size of the number pool reserved for TTN service, we assume that the TTN requests form a Poisson process with arrival rate λ, and the active time period of a TTN has a general distribution with mean $1/\nu$. Let P_b denote service blocking probability that when a TTN service user requests a TTN, no free TTN is available, i.e., all TTNs are either active or aging.

Let c denote the size of temporary telephones number pools reserved for TTN services. The service can be described by an *M/G/c* queueing system, where the inter-arrival time of the requests of TTN service is exponential distributed with mean $1/\lambda$, and the expected service period is $1/\mu = 1/\nu+90$ (the expected active time plus 90 days of aging period). The blocking probability (P_b) can be obtained by the Erlang loss formula.

$$P_b = \frac{\left(\frac{\lambda}{\mu}\right)^c/c!}{\sum_{i=0}^{c}\left(\frac{\lambda}{\mu}\right)^i/i!} \tag{1}$$

Since the desired blocking probability needs to be below 0.1%, from Eq. (1), we can obtain the minimum size of the reserved number pool.

B. The Proposed TCN Service

For the TCN service, we make the same assumptions as for the TTN service that the TCN requests form a Poisson process with arrival rate λ, and the active time period of a TCN has a general distribution with mean $1/\nu$. Note that a TCN request can be fulfilled by assigning an unused TCN for the communications between the requestor and the correspondent party, i.e., the TCN is assigned on a per correspondent-party basis. Therefore, we consider the size of the number pool reserved for a given correspondent party. We make an additional assumption that the specified correspondent parties of all TCN requests are uniformly distributed among all PSTN users. Let N denote the total number of users in the PSTN under consideration. The TCN service can be described by an *M/G/c* queueing system where the TCN requests for a given correspondent party form a Poisson process with arrival rate λ/N, since we assume that the correspondent parties of TCN requests are uniformly distributed among all PSTN users. The expected service period of a TCN is the same as that of a TTN, i.e., equals to $1/\mu$ (= $1/\nu+90$). The blocking probability (P_b) can be also obtained by the Erlang loss formula as follows.

$$P_b = \frac{\left(\frac{\lambda}{N\mu}\right)^c/c!}{\sum_{i=0}^{c}\left(\frac{\lambda}{N\mu}\right)^i/i!} \tag{2}$$

Note that the blocking probability obtained in Eq. (2) is the average blocking probability of all correspondent parties. Now, we turn our focus to a stricter requirement – the highest blocking probability among all corresponding parties.

Since the arrival rate if TCN requests for each correspondent party is small (λ/N), we assume that a sufficient amount of telephone numbers has been reserved, so that the service for a given correspondent party can be approximated by an $M/G/\infty$ queueing system, where the arrival rate is λ/N and the expected service period is $1/\mu$ (=$1/\nu$+90).

When a TCN is assigned for the communications between a subscriber and a correspondent party, the TCN is active for the correspondent party. When the TCN is released by the subscriber, it stays in the aging pool for 90 days before it can be re-assigned for communications with the same correspondent party. Let q_i denote the steady state probability that i TCNs are active or in the aging process for a given correspondent party. We have

$$q_i = \frac{\left(\lambda/_{N\mu}\right)^i e^{-\frac{\lambda}{N\mu}}}{i!} \quad \text{for } i = 0\,..\infty \tag{3}$$

Let X denote the number of active and aging numbers for a given correspondent party, and $F(x)$ denote the distribution function of X. We can obtain

$$F(x) = \Pr[X \le x] = \sum_{i=0}^{x} q_i = e^{-\frac{\lambda}{N\mu}} \sum_{i=0}^{x} \frac{\left(\lambda/_{N\mu}\right)^i}{i!} \tag{4}$$

Let Y denote the maximum of active and aging numbers among all correspondent parties and $G(y)$ denote the distribution function of Y. Since we assume that the specified correspondent parties of all TCN requests are uniformly distributed among all PSTN users. The X's of all correspondent parties are independent and identically distributed. $G(y)$ can be determined by order statistic. We have

$$G(y) = \Pr[Y \le y] = F^N(y) = e^{-\frac{\lambda}{\mu}} \left(\sum_{i=0}^{y} \frac{\left(\lambda/_{N\mu}\right)^i}{i!} \right)^N \tag{5}$$

Since N, the number of users of a PSTN operator, is usually very large. Eq. (5) can be approximated as follows. From Taylor's theorem [5], we have

$$e^{\frac{\lambda}{N\mu}} = \sum_{i=0}^{y} \frac{\left(\lambda/_{N\mu}\right)^i}{i!} + R_y\left(\frac{\lambda}{N\mu}\right) \tag{6}$$

$$R_y\left(\frac{\lambda}{N\mu}\right) \le e^{\frac{\lambda}{N\mu}} \frac{\left(\lambda/_{N\mu}\right)^{y+1}}{(t+1)!} \tag{7}$$

From Eqs. (5-7), we have

$$G(y) \ge e^{-\frac{\lambda}{\mu}} \left(e^{\frac{\lambda}{N\mu}} - e^{\frac{\lambda}{N\mu}} \frac{\left(\lambda/_{N\mu}\right)^{y+1}}{(y+1)!} \right)^N$$

$$= \left(1 - \frac{\left(\lambda/_{N\mu}\right)^{y+1}}{(y+1)!} \right)^N \approx 1 - \frac{\left(\lambda/_{\mu}\right)^{y+1}}{N^y (y+1)!} \tag{8}$$

Let s denote the minimum size of the reserved number pool so that a desired blocking probability, P_b, can be accomplished. s can be obtained by

$$\min_s G(s) > 1 - P_b \tag{9}$$

From Eqs. (8-9), we can obtain

$$\min_s \frac{\left(\lambda/_{\mu}\right)^{s+1}}{N^s (s+1)!} < P_b \tag{10}$$

In our numeric analysis, the desired service blocking probability was chosen to be 0.1%, and we intended to know the minimum size of the number pool reserved for TCN service when the average or the worst service blocking probability is considered. The total number of PSTN users was assumed to be 100,000, which is a very conservative number, since a PSTN operator usually serves millions of users. Note that a larger number of PSTN users would reduce the size of the reserved number pool because the TCN request rate for each correspondent party (λ/N) decreases as N increases. The expected service period ($1/\mu$) was assumed to be 120 days, i.e., an active period of 30 days plus an aging period of 90 days.

Figure 2 depicts the minimum size of the reserved number pool increases as the TCN request rate increases from 1/day to 100,000/day. The results were obtained from Eqs. (2) and (12). The results indicate that only a very small size of number pool is needed for TCN service. If the average service blocking probability is considered, when the TCN call request rate is as high as 100,000/day, only 24 telephone numbers are needed. If the worst service blocking probability among all correspondent parties is considered, less than 50 telephone numbers are needed for the TCN request rate at 100,000/day. By contrast, when the TTN request rate is as low as 100/day, the conventional TTN service would require more than 12,000 telephone numbers, since the expectation of active and aging numbers is 12,000 (λ/μ).

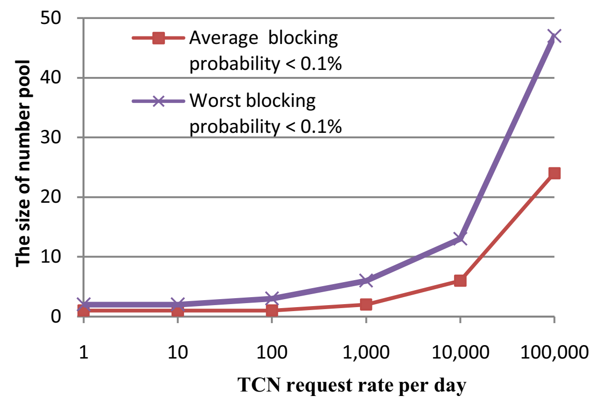

Figure 2. The minimum size of number pool for TCN service.

IV. Conclusions

Conventional temporary telephone number service requires a very large size of temporary number pool. In this paper, we present a restricted form of temporary telephone number service – temporary call-back telephone number service. A temporary call-back number is not a secondary telephone number assigned to a subscriber; instead, it can only be used by the subscriber-specified correspondent parties to reach the subscriber. In this way, the same call-back number can be assigned to different subscribers as long as their specified correspondent parties are different. As a result, the size of the number pool reserved for temporary call-back number service is significantly reduced. We have also presented a numeric analytic model to estimate the size of the reserved number pool. The analytic results show that temporary call-back telephone number service requires less than 50 telephone numbers even when the service requests are as high as 100,000 requests per day for a PSTN population of 100,000 users. Moreover, the telephone number mapping table used in this service can also be used for the short message service and multimedia messaging service in the cellular communication network. However, this service is not a replacement for the conventional temporary telephone number service. It only provides call-back numbers for a group of correspondent parties specified by the subscriber

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