Quantifying the Presence of Phone Users

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Abstract - **Presence-enabled telephony services can reduce telephone tag and improve customer satisfaction. In this paper we proposed the Bayesian inference model to calculate the *willingness level* of the callee to accept calls. Before making a call, the caller may use the willingness calculator to find out whether the callee is available. *Based on this level* the user can make a decision whether to make a call. For validation of our results, we used actual call logs of 100 users collected at MIT by the Reality Mining Project group for a period of 8 months. We used time of the day, day of the week, talk-time and location for calculating the *willingness level. Our* results show a good agreement between computed *willingness level* and the number of missed/rejected calls. This service can be included as part of the presence server. When deployed, this service can increase productivity, avoid unwanted calls and reduce the call traffic congestion. This service is beneficial to both subscribers and phone service providers. However, in order to make this service a reality, we need to take into account other factors such social closeness, proximity, multiplexity and reputation of the caller.** *

I. INTRODUCTION

The emerging of presence-aware communications allows people to quickly connect with others, whether on the road, in meetings, or working from remote locations, via the best choice of communication means. Presence awareness lets users know when other people in their contact list are online. Presence information can include more user details, such as availability, location, activity, device capability and other communication preferences. Presence would answer the questions of Who (user), Where (location and device), When (preference and willingness), How, (device capability) and Why (information exchange, leisure, keeping in touch etc) [1].

Presence is used to detect and convey one's willingness and ability to talk on the phone. Presence-enabled telephony services can reduce telephone tag and improve customer satisfaction. The usual concept of presence is that of explicit presence, consisting of geographical location and the online/offline status of a device. The fundamental presence reflects changes in a person's context [2]. The context of our daily life activity is useful as presence information. Presence information can include a variety of functions, like availability, communication preferences, device capability, identity, as well as a person's intent [2]. Context can include information concerning the location, user identity, device, proximity of people and devices, and time. In this study we consider context in relation to the interpersonal communication that can take place.

Presence technology has been applied in instant message (IM) system. The popular IM systems include the AOL / ICQ IM system, Microsoft's MSN Messenger, Yahoo Messenger and etc. In these IM systems the user have a present user agent which serve as a person's unique identifier. When a user want to contact someone, he/she clicks on the name in an e-mail address book. The system contacts the intended receiver's presence user agent. The present user agent will find the receivers based on their addresses and then lists various contact points such as home or phone number, or e-mail address.

Recently the presence service has been integrated in some mobile handsets. The Instant Messaging and Presence Services (IMPS) specification was developed by the Wireless Village consortium. It was later united into Open Mobile Alliance (OMA) IMPS [3]. It is allowed to deliver the different types of presence information and to control the distribution by the user in the specification. In Push-to-Talk over Cellular -enabled handsets, the method for presence is based on the Session Initiation Protocol (SIP) [4].

In [5] a 3-layer uninterrupted communication system was proposed using SIP with presence-aware technology. In [6] the SIP was used to create presence architecture. In [7] the authors' work was to reduce enterprise server load by mobile clients sharing presence information with a network and only one of the client acts as a gateway to interact with the server to supply the presence information of the network. In [8] the authors developed the BusinessFinder, a service that can track and use the location of both requesting users and vendors to match users to nearby vendors, use a variety of channels (such as IM, SMS, or voice) to capture the true availability of such nomadic vendors, and use community-feedback to eliminate poor-performing vendors from its directory. In [9] the automatic location detection system was investigated as part of a mobile presence system. This study was focused on analyzing how the persons named locations

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and how they used location information in the context of mobile presence. In [10] the authors investigated presence-in-absence in terms of its social (Contact) and informational (Content) aspects, and the surroundings of the experience (Context).

The existing presence servers provide presence information such as *Online, Available, Away* and *Do not disturb*. But they do not provide the presence level or willingness level. In this paper we built a model to compute the willingness level to complement this defect.

In this paper we propose the Bayesian inference model to compute the willingness level of a receiver in a given time. In Section 2 the methodology for computing the willingness level of the callees to accept calls is described. In Section 3, we described the Bayesian inference model to compute willingness level of callees. We performed the experiments with the actual call logs and discussed the results in Section 4. Next, we verified that indeed the receiver rejected the calls when the willingness was low. The validation of our model is conducted by the actual call logs and described in Section 5. Finally, we have the conclusions in Section 6.

II. Methodology

When a caller wants to make a call, he would like to know if the callee is in a mood to receive a call. In other words the callers would like to know when it is a good time to call the particular callees. We estimate the chance based on the time of the day, call duration and the location.

Time of the day: Everyone has his/her own schedule for working, studying, entertainment, sleeping, traveling and so on. The schedule is mainly based on the time of the day and day of the week. The callees do not want to take calls during their busy hours or sleeping.

Call duration: The call duration is how long both caller and callee want to talk each other. The longer the call duration is, the more willing to talk each other for the caller and callee are.

Location: The callee mostly would not like to take the calls when he/she is working at particular location and would like to take the calls at home. So we estimate the callee's willingness to take the call based on the callee's location.

Unwanted call rate: we define the unwanted call rate as a ratio of number of missed calls to the number of calls at given time period.

The caller usually wants to know the callee's willingness and based on that decides whether to initiate a call. From the network traffic control point of view, this can reduce traffic congestion since the caller knows the callee's willingness level so the caller might not initiate a call and also save the caller's available minutes. Therefore, we propose the Willingness Calculator (WC) for computing the willingness level of the callee, which can be deployed at the callee's Home Location Register (HLR in a cellular network). The WC service flow diagram is shown in Fig. 1.

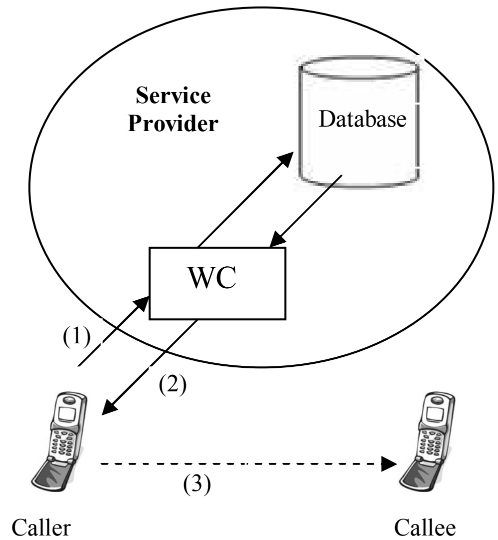

Fig.1 Basic service flow diagram

We foresee a button on the phone called "presence" and caller dials a number and presses this button instead of a dial button. Then, phone sends a request to the WC for callee's willingness level. Next, the WC take the information of current time of the call, current weekday/weekend, the callee's location information, and the call history from the database. The WC computes the willingness level based on the Bayesian inference method and forwards the result to the caller. The caller can decide whether or not to initiate the call based on the willingness level of the callee.

***Real-life traffic profile*:** In this paper, the actual call logs are used for analysis. These actual call logs are collected at MIT [11] by the Reality Mining Project group for a period of 8 months. This group collected mobile phone usage of 100 users which including their user IDs (unique number representing a mobile phone user), time of calls, call direction (incoming and outgoing), incoming call description (missed, accepted), talk time, and tower IDs (location of phone users). These 100 phone users are students, professors and staffs. The collection of the call logs is followed by a survey of feedback from participating phone users for behavior patterns such as favorite hangout places, service provider, talk time minutes, phone users' friends, relatives and parents. We used this extensive dataset for our willingness level analysis and validation of 10 sample users in this paper. More information about the Reality Mining Project can be found in [11].

We used Bayesian inference method to build our model to compute willingness level of callees to accept incoming calls. Bayesian inference uses a probability model for both observed and unobserved quantities. It uses probability to express knowledge about unknown quantities. Let X and Y

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be two events. By conditional probability rule [12], the probability of an event X given Y is

$$P(X \mid Y) = \frac{P(X,Y)}{P(Y)} \quad (2.1)$$

where P(X,Y) is joint probability.
By the chain rule of conditional probability [2], we have

$$P(X,Y) = P(X \mid Y)P(Y) \quad (2.2)$$

Since it does not matter to choose the order of X and Y in the equation (2.2), we have

$$P(Y, X) = P(Y \mid X)P(X) \quad (2.3)$$

Since P(X,Y) = P(Y,X), we have

$$P(X \mid Y)P(Y) = P(Y \mid X)P(X).$$

Thus, we have Bayes' theorem:

$$P(X \mid Y) = \frac{P(Y \mid X)P(X)}{P(Y)} \quad (2.4)$$

In equation 2.4, P(X | Y) is called posterior probability, P(Y | X) is referred to as likelihood and P(X) is prior probability.

III. System Model

To find the willingness level of a user to accept a phone call at a particular time of the day, we use Bayesian inference method.

Willingness by number of calls

$$P_f(T_i, D_j, Loc_l) = P_f(T_i)P_f(D_j)P_f(Loc_l \mid T_i, D_j) \quad (3.1)$$

$$P_f(T_i \mid D_j, Loc_l) = \frac{P_f(D_j \mid T_i, Loc_l)P(T_i \mid Loc_l)}{P(D_j \mid Loc_l)} \quad (3.2)$$

Where T_i is time interval, i = 0, 1, 2, …23, (e.g. T_0 : 0 – 1 O'clock),

D_j is a day, j=1,2, …, 7 ie. D_1 = Sunday, D_2 = Monday, …

D_7 = Saturday.

Loc_l = location name, l=1, 2, …n

$$P_f(T_i = t) = \frac{number\_of\_calls\_in\_interval\_t}{total\_number\_of\_calls} \quad (3.3)$$

$$P_f(D_j = Sunday) = \frac{number\_of\_calls\_on\_Sunday}{total\_number\_of\_calls}$$

(3.4)

$$P_f(D_j \mid T_i, Loc_l) = \frac{P_f(T_i \mid D_j, Loc_l)P(D_j \mid Loc_l)}{P_f(T_i \mid Loc_l)} \quad (3.5)$$

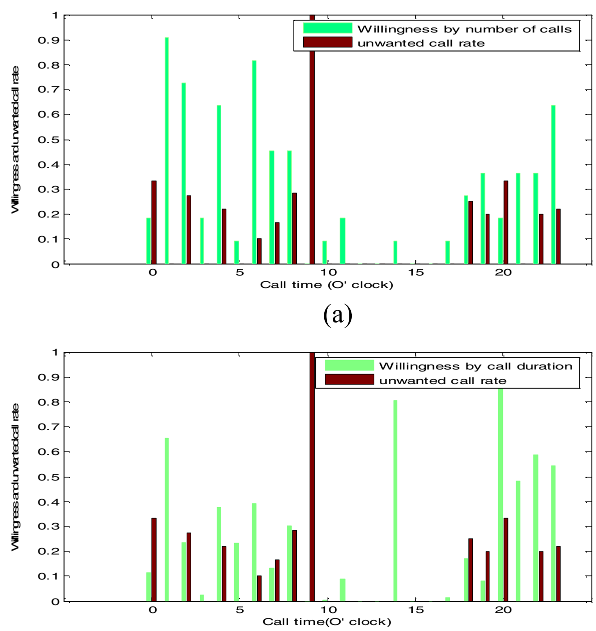
We computed the willingness for each hour for all weekdays and weekend.

IV. Experiment Results And Discussion

We calculated the willingness level to receive calls and the corresponding unwanted call rate for users for one hour interval from 0 – 23 O'clock from Sunday to Saturday.

In the Figs. 2 and 3 the x-axis indicates the calling time for incoming as well as outgoing calls for 24 hours on Sunday and Monday and the y-axis indicates the willingness level for a second year graduate student user. In this graph, missed calls are considered as unwanted calls and these are compared with willingness level. When the willingness level is low, then there are more missed calls.

Fig. 2(b) describes the willingness calculated based on total talk time. From Fig. 2 (a) and (b) we can see that when the user is more wiling to receive calls, then less missed calls. The receiver is missing calls means these are unwanted calls at a given time. For example, in Fig. 1 (a) the willingness level is 0.7 (70%) and corresponding unwanted call rate is 0.28 (28%) between 2 to 3 O'clock. One more example, the willingness level is 0.2 (20%) and the corresponding unwanted call rate is 0.33 (33%) between 0 to 1 O'clock.



(a)

(b)

Fig. 2 Willingness level on Sundays. (a) willingness level compared to unwanted call rate (rejected/missed) (b) computed willingness level based on talk time

Fig. 3 shows the willingness level of this user on Mondays. From Fig. 3 (a) and (b) we can see that higher willingness level corresponds to lower unwanted call rate. For example,

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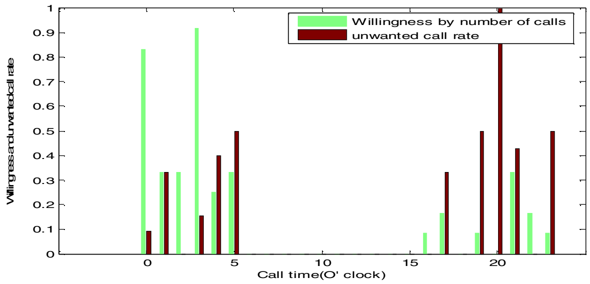
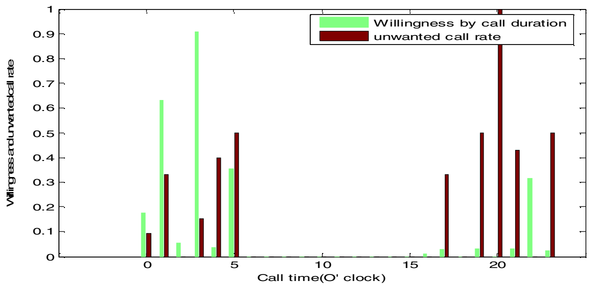
in Fig. 3 (a) the willingness level is 0.84 (84%) and the corresponding to unwanted call rate is 0.1 (10%) between 0 to 1 O'clock. Next, the willingness level is 0.1 (10%) and the corresponding to unwanted call rate is 0.5 (50%) between 23 to 0 O'clock.



(a)



(b)

Fig. 3 Willingness level and unwanted rate on Monday. (a) Willingness level and unwanted rate by number of calls (b) Willingness level and unwanted rate by call duration

Fig. 4 shows the willingness level of this second year graduate student user based on the number of calls he received from Sunday to Saturday. Here x-axis represents time of the day, and the y-axis represents 7 days of a week. The first unit on the y-axis represents Sunday and the last unit represents Saturday.

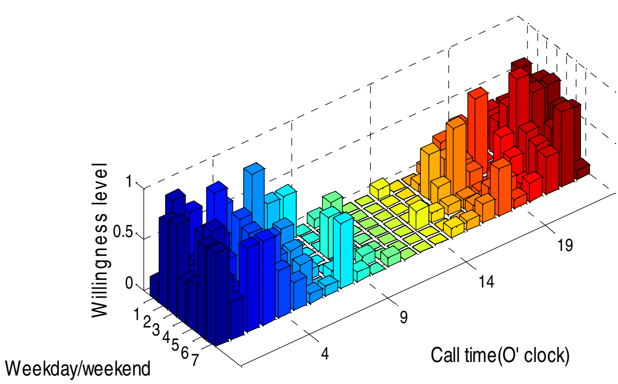


Fig.4 Willingness level during 24 hours from Sunday to Saturday

Fig. 5 shows the willingness level of this user based on the location. From Fig. 5 we can see that the callee is more likely to take calls at home.

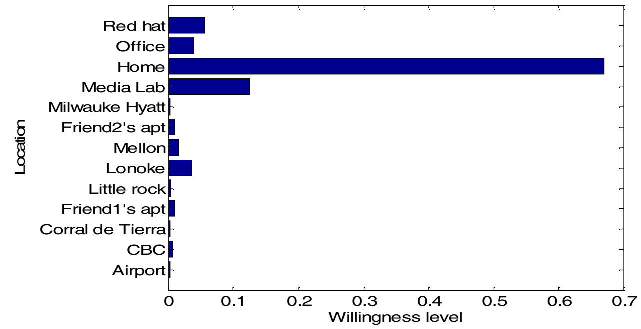


Fig. 5 Willingness level based on location

Another callee's willingness level, who is a fifth year Ph.D. student, based on location is shown in Fig. 6. From Fig. 6 we can see that this callee is more likely to take calls at the place "ny" than that at home.

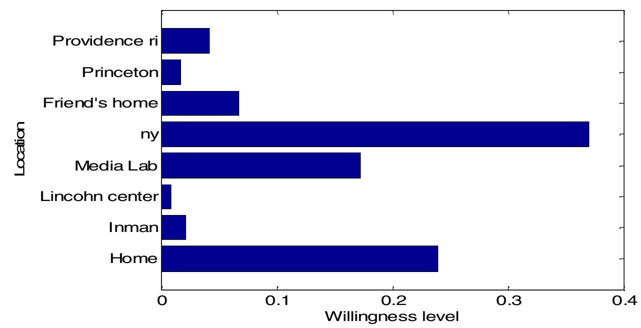


Fig. 6 Willingness level based on location

V. Validation

To evaluate the accuracy of our model, we use actual call logs of 100 phone users and randomly choose 10 phone users. These users include students, professors and staffs. This data was collected during a period of 8 months. We have used the first six months of data and computed the willingness level for the next two months. Next, we validate this willingness with respect to number of missed or rejected calls.

The accuracy is measured by the unwanted call rate over the range of different willingness levels. The unwanted call rate is a ratio of number of missed calls to the total number of calls at given time period. The assumption is that a missed call is an unwanted call.

Table 1 and Fig. 7 describe the experimental results for 10 phone users. Table 2 describes the accuracy of our results. In this table, we calculated several statistical parameters of willingness level. In Tables 1 and 2 the results show that our model achieves good performance with high accuracy. For example, when the willingness level is 0 - 30%, the average

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unwanted rate is 43.32% with standard error 1.79%. Whereas the mean unwanted rate is 4.84% for the willingness of 71-100%. The higher the willingness level, the lower will be unwanted rate, and vice versa.

TABLE I
UNWANTED CALL RATE CORRESPONDING TO THE WILLINGNESS LEVEL

Phone users	Number of incoming calls	Number of unwanted calls	Unwanted rate (%)		
			Willingness level (%)		
			0-30	31-70	71-100
1 (student)	564	128	41.3	14.3	7.4
2 (staff)	230	68	45.7	8.1	2.7
3 (professor)	341	52	32.7	11.5	3.3
4 (student)	563	88	45.9	11.1	6.3
5 (student)	1007	195	35.1	17.8	8.8
6 (professor)	255	53	42.4	13.8	1.1
7 (staff)	186	55	47.6	14.6	2.1
8 (student)	487	180	49.8	16.9	4.6
9 (student)	361	143	48.9	12.0	4.9
10 (student)	286	69	43.8	10.1	7.2

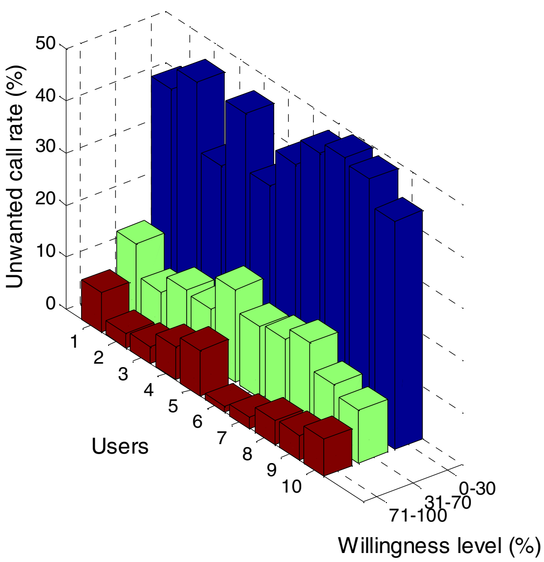

Fig. 7 Willingness level (%) vs. unwanted call rate (%) for 10 users

TABLE II
DESCRIPTIVE STATISTICS FOR UNWANTED RATE

	Unwanted rate (%)		
Willingness level (%)	0-30	31-70	71-100
Mean	43.32	13.02	4.84
Standard Error	1.79	0.95	0.80
Standard Deviation	5.66	3.02	2.55
Count	10	10	10

VI. CONCLUSION

In this paper we proposed the Bayesian inference model for calculating the willingness level of the callee. Before making a call the caller may use the willingness calculator to find out whether the callee is available. Based on this level the user can make decision whether to proceed and make a call. If the willingness level is high, the call most likely will be answered; otherwise the call will be possibly rejected or forwarded to the voice mail. The experimental results show that our model achieves good performance with high accuracy. When the willingness level are 0 - 30%, 31-70% and 71-100%, the average unwanted rate are 43%, 13% and 5% respectively. In practice, the caller will be prompted a message like *"the availability of the person you are calling is very low/low/medium/high"*. This service can help the phone users to decide when is a good time to call and save their time. This service can also reduce unwanted call traffic and reduce the nuisance level to the callees. Overall, the reduction of unwanted calls can reduce the call traffic congestion in a cellular network. Therefore it is beneficial to both the customers and phone service providers.

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