AdChatRep: A Reputation System for MANET Chatting

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ABSTRACT
A Mobile Ad Hoc Network (MANET) is becoming a practical platform for pervasive social networking. People chat with each other via MANET for instant social activities. How to help mobile users to build up trust in MANET chatting is becoming an interesting issue. We design AdChatRep, a reputation system for MANET chatting based on the result of a need assessment survey. We implement it by applying Nokia N900 smart phones as MANET nodes. We further conduct a two-session controlled user experiment to investigate the impacts of AdChatRep on mobile users. Results show the effectiveness of AdChatRep with regard to its usefulness and user acceptance.

Author Keywords
Social Networks, Reputation Systems, MANET, Trust.

ACM Classification Keywords
H.5.2. [**Information Interfaces and Presentation**]: User Interfaces – user centered design, prototyping, evaluation/methodology, theory and method

General Terms
Design, Experimentation, Human Factors, Verification.

INTRODUCTION
A Mobile Ad Hoc Network (MANET) is a collection of autonomous nodes that communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner. Nowadays, MANET has a good prospect of becoming a practical platform for instant social activities [1]. For example, a user could chat with strangers nearby for sharing a taxi ride, sharing the cost of on sale products, or bulling. This kind of pervasive social networking is an essential compensation of internet social networks, thus very valuable for mobile users, especially when fixed networks (e.g., Internet) or mobile networks are temporarily unavailable or costly to access. It also provides a good way to preserve user privacy, more advanced than traditional social networking systems, e.g., facebook.

During chatting, how much should the user trust with each other in order to make a decision? This introduces a demand to provide a practical reputation system for MANET based pervasive social networking that could intelligently assist mobile users and encourage good behaviors. Herein, trust is defined as the belief regarding the reliability, integrity, ability, or characters of an entity. Reputation is a measure derived from direct or indirect knowledge/experience on earlier interactions of entities and is used to assess the level of trust put into an entity [11].

In this paper, we develop AdChatRep, a reputation system for MANET chatting by applying a methodology we proposed for developing usable trust management [6]. We design a reputation scheme for AdChatRep according to users' concern on trust during MANET chatting and their preferences on reputation visualization. We implement the system using Nokia N900 as MANET nodes. Furthermore, we validate the effectiveness of AdChatRep through a two-session controlled user experiment with regard to its usefulness and user acceptance.

In the rest of the paper, we first review related work. Then, we introduce a need assessment survey to investigate how users consider and expect to cope with a reputation system for MANET chatting. Next, we describe the design and implementation of AdChatRep. Thereafter, we report experiments conducted to test the impact of introducing AdChatRep into MANET chatting. We further analyze the data collected from our user study to ascertain research results and implications. Finally, we conclude by discussing the contributions of this paper and suggesting future work.

RELATED WORK
Trust and reputation mechanisms have been widely studied in various fields of distributed systems, such as ad hoc networks, peer-to-peer (P2P) systems, Grid computing, pervasive computing and e-commerce [2]. Many mechanisms have been developed for supporting trusted communications and collaborations among computing nodes [9-11]. Some work evaluates trust based on social relationships [12]. In these researches, trust can be modeled, calculated and thus expressed using a value. However, none of the above studies consider how to evaluate trust and reputation based on social networking behaviors and experiences, especially in the context of MANET. Little work in the literature develops a reputation system driven by users' concern [6].

AdChatRep has similar social networking functions to a number of research projects, such as Micro-blog [3] and AdSocial [4]. However, trust and reputation support are not considered in these projects. Traditional centralized social networking systems (e.g., facebook) have not taken user privacy into account. They cannot support instant social

SCI'11, September 18, 2011, Beijing, China.

networking demands, especially when users do not have internet connection, but with location proximity.

A lot of work has been conducted regarding user interface design in order to improve user's trust, mainly for web sites and in the context of e-commerce [5, 7]. In many existing web services (e.g. eBay.com and Amazon.com), reputation values (mostly in a Likert scale) are displayed based on rating in order to assist users' decision. Still, prior art left rooms for further studies on the effects of visualizing reputation on pervasive social networking and, in particular, on how to provide trust information to mobile users.

In AdChatRep, we use a reputation indicator to indicate each user's local reputation during chatting and provide detailed information about local reputation evaluated by the user's mobile device and general reputation issued by a trusted server. They are interface design elements that provide the cue of trust information in MANET chatting. But few previous researches investigated visualizing reputation's effects on mobile users in the context of pervasive social networking, which is one of our research targets in AdChatRep [13].

NEED ASSESSMENT

We conducted a need assessment survey before designing and implementing AdChatRep in order to explore its potential usefulness, the main factors that influence trust during MANET chatting and the user's preference with regard to reputation visualization. We applied a 5-point Likert scale in the survey.

Design

The survey contains three parts. The first part evaluates the potential significance of developing AdChatRep based on three MANET chatting scenarios:

Scenario 1: sharing the cost of ´buy 3 pay 2´ goods in a shopping mall: Right now you are at a shopping center, and a product you want is on sale with a condition ´buy 3 pay 2´. However, you only need one. You want to ask people nearby, whom you don't know, via your mobile phone whether he/she wants to share the discount with you.

Scenario 2: sharing the price of a packet of 5 movie tickets in front of a movie theater: After shopping, you want to watch Avatar in a movie theater. The ticket price is 13.8e. However, if you buy a packet of 5 tickets, it will be 8.6e for each. You want to share the ticket packet with people nearby whom you don't know. You discuss whether he/she wants to share the discount with you via your mobile phone.

Scenario 3: sharing a taxi ride after movie: After the movie, a lot of people are leaving the theatre. You want to watch a figure skating competition quite far away. You would like to take a taxi and think about sharing a ride. You discuss with people nearby via your mobile phone whether he/she wants to share the ride with you.

The participants were asked to express their opinions on the usefulness of a reputation system in the above MANET chatting scenarios.

The second part explores the factors that may influence a user's trust in MANET chatting. We examined 5 factors: 1) chatting topic's crucial level (*cl*); 2) depth of chatting (*dc*); 3) interest similarity (*is*); 4) on-chat voting (*cv*); 5) afterwards voting (*v*), as defined in Table 1. We also designed a measurement scale (i.e., the items in Table 1) to measure these factors in the survey in order to justify which ones should be considered in AdChatRep. We asked the participants to mark their agreement on the items.

Factors	Definition	Items
chatting topic's crucial level (cl)	The criticality of chatting content and purpose	1) I am generally cautious when chatting on a crucial topic. 2) It is easier for me to talk more in less crucial or important chat. 3) I am careful to disclose my personal information in crucial chat.
depth of chatting (dc)	The rounds of communications and interactions between two parties	4) I will chat more with others if I feel good to continue talking. 5) I need to chat with a person many rounds in order to make a decision. 6) It is important for me to ask a number of important questions during chatting in order to make a decision.
interest similarity (is)	The common chatting communities shared between two parties	7) I feel safe to chat with a person if he/she chatted with me before. 8) I feel easy to chat with a person if I chatted with him before. 9) I feel good if a person chat with me several things with common interests.
on-chat voting (cv)	The vote on some specific message provided by a chatter during chatting	10) I would like to express my opinion on somebody's words during chatting. 11) I would like to know other people's opinion on somebody else during community chatting. 12) I trust a person more if I can follow his/her words more.
afterwards voting (v)	The vote on a party after chatting based on interaction experiences	13) It is helpful to know other people's opinion on a person after chatting. 14) I can evaluate a person more accurately after chatting than during chatting. 15) I can evaluate a person even more accurately when I physically interact with him/her.

Table 1. Factors influencing trust in MANET chatting.

The third part attempts to study the user's preference on reputation visualization UI design. We proposed 4 visualization methods, as illustrated in Table 2: UI1 – reputation is indicated based on the font size of a chatter's input text; UI2 – reputation is indicated by the number of stars; UI3 – reputation is indicated through a growing process of a cartoon character; UI4 – reputation is indicated through a role in a community, which can be personally specified by a user. We asked the participants to mark their preferences. Note that UI2 is a traditional reputation visualization method applied by Amazon and eBay.

Reputation visualization methods
UI1) Based on the font size of a chatter's input text: the bigger size of the font, the more reputable
UI2) Based on the number of stars, the more the better reputation, e.g. ★★★★☆
UI3) Through a growing process of a cartoon character, the more mature the more reputable, e.g.
UI4) Through a role in a community, a user can personally select or define the roles and their represented reputation, e.g. Little reputable history with trouble records Some reputable history with trouble records Some reputable history without trouble records High reputation with some trouble records High reputation without trouble records

Table 2. Reputation visualization methods.

Participants and Results

The survey was distributed through a mailing list. We conducted it in Finland and collected the survey response via email. A movie ticket was awarded to each participant. We got totally 34 responses; among them 27 were university students, 21 male and 13 female, 3 participants were over 36 years old, the rest were between 22-28. All of them had Internet chatting experiences, 70.6% had mobile Internet chatting experiences, but none of them had experience on MANET chatting.

The survey result and its implication are summarized as below:

1. The average rating scales regarding the potential usefulness of a reputation system in three MANET chatting scenarios were 3.71 (SD=1.00), 3.85 (SD=.96) and 4.09 (SD=.87), respectively. All of them are over 3.5. This implies that a MANET chatting reputation system is potentially thought as useful in some instant social networking scenarios. Therefore, it is significant for us to design and develop such a system.

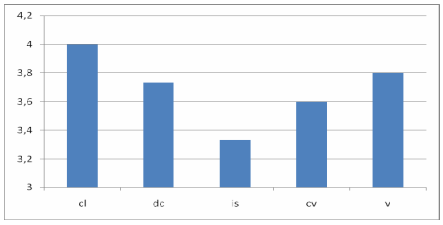


Figure 1. Agreement scales on the factors influencing trust.

2. As shown in Figure 1, the average agreement scales of the five factors were ranged between 3.33 and 4.00. This implies that these five factors influence trust and should be considered in the design of AdChatRep reputation scheme. The survey provides us a good justification.

3. Most participants preferred the traditional reputation visualization style UI2 (with an average value 4.10), but they were also interested in the new styles UI3 and UI4 proposed by us (UI3=3.24 and UI4=3.12). However, the font size based reputation indication was not preferred (UI1=2.29). Thus, personalized reputation visualization is suggested in AdChatRep.

SYSTEM DESIGN AND IMPLEMENTATION

Based on the survey results, we designed and developed AdChatRep, as described below.

System Structure

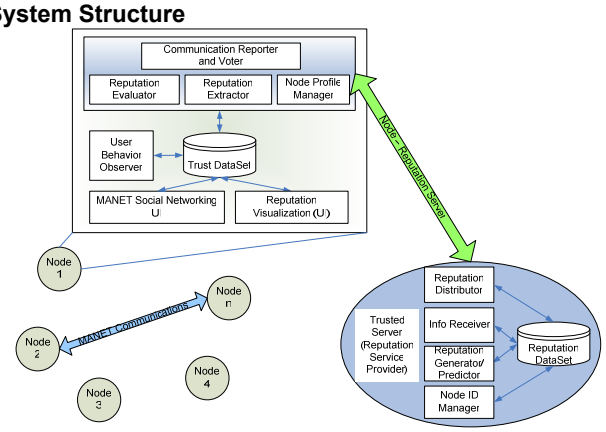


Figure 2. AdChatRep system structure.

Figure 2 illustrates the structure of AdChatRep. At each node device, a User Behavior Observer records node chatting behaviors. A MANET Social Networking UI provides a user interface for social networking. Communication Reporter and Voter report the communication records and local reputation to a Trusted Server (TS). Meanwhile, the user can also vote other entities through it to TS. A Reputation Evaluator evaluates the node reputation and provides it to the user via a Reputation Visualization UI during chatting. A Reputation Extractor receives the reputation token that contains the node reputation value issued by TS. Trust DataSet securely stores all related data. A Node Profile Manager maintains node user's personal information. It can communicate with TS to register the node into AdChatRep and update the node user's pseudonym and reputation token.

At the TS, a Reputation Generator/Predictor calculates the node reputation values and identifies malicious nodes. A Reputation Distributor distributes the reputation tokens to each node periodically or by request. A Node ID Manager handles node registration and manages pseudonyms. An Information Receiver collects the records reported by the nodes and saves them into Reputation DataSet, which also saves the reputation tokens and the nodes' real IDs and their pseudonyms. Applying node pseudonyms in AdChatRep during chatting can enhance user privacy, but TS can still precisely provide general reputation based on historical social networking records according to real node identities.

Reputation Generation

AdChatRep generates node user reputation based on the following model. The TS generates/predicts node reputation and issues a reputation token to the node. Based on the reputation token attached to each node and MANET social

networking experience, a node generates the reputation of other nodes during chatting. Other nodes' reputation values are further evolved based on their social networking behaviors and performance. Particularly, the node reports past chatting experiences or vote other users who chatted with him/her to TS. After collecting additional MANET social networking records, TS updates each node's general reputation value according to his/her performance. The evaluation of node reputation is iterative at the node and TS based on newly accumulated experiences and information.

To generate a node user's on-chat reputation, we apply Formula (1) by considering the first four on-chat factors explored in the survey:

$$R(i \to j) = \alpha\left(R'(i \to j) + R(j)\right) + \beta \sum_{l=1}^{L} \{cv(i \to j)_l * dc(i,j)_l\} * is(i,j) * cl(i) + \gamma \sum_{k \neq i} \sum_{l=1}^{L'} \{cv(k \to j)_l\} * R(i \to k) \quad (1)$$

where $R(i \to j)$ is node i's local evaluation on node j's reputation. $R'(i \to j)$ is node i's evaluation on node j's reputation predicted and issued by TS, or previous node i's reputation evaluation on node j. $R(j)$ is node j's global reputation issued by TS. $cv(i \to j)_l$ is the lth on-chat voting on node j's message by node i. $is(i,j)$ is the number of common communities shared by i and j, which indicates their common interests. $cl(i)$ is the crucial level of chatting topic. $dc(i,j)_l$ is the depth of chatting between node i and j at the time of j's lth voting.

Formula (1) is composed of three parts. The first part is the sum of previous on-chat reputation and the global reputation, which serves as the initial reputation of current chatting. The second part is the reputation generated on the basis of current chatting experience. Since there could be multiple on-chat votes during chatting, we integrate them together by averaging the product of on-chat votes and the depth of chatting at the vote that impacts the preciseness of a chatter's opinion. The depth of chatting is the minimum number of input messages between node i and j. Furthermore, this part is weighted by $is(i,j)$ and $cl(i)$, which are other two on-chat factors influencing trust. The third part is generated based on the on-chat votes on node j provided by other nodes than i, which is certified by node i's local evaluation on node k's reputation $R(i \to k)$. α, β, γ are parameters to indicate the weights of different contributions. They can be set based on the users' concern achieved in our survey. Note that $\alpha + \beta + \gamma = 1$.

Based on afterwards voting and on-chat reputation, we generate two types of node reputation at TS: personalized reputation and general reputation. We apply weighted aggregation using on-chat reputation as credibility to overcome unfair rating and also consider time's influence on the afterwards voting in order to overcome on-off and conflict behavior attack [8].

Formula (2) is applied to generate personalized reputation of node j $\overline{R(i \to j)}$ evaluated by node i by considering the fifth factor – afterwards voting and time decaying:

$$\overline{R(i \to j)} = \frac{1}{O} \sum_{m} R(i \to j)^{t_m} * V_i^{j(t_m)} e^{-\frac{|t - t_m|^2}{\tau}} \quad (2)$$

where $O = \sum_{m} R(i \to j)^{t_m} * e^{-\frac{|t - t_m|^2}{\tau}}$; $V_i^{j(t_m)}$ is node i's afterwards voting on node j at time t_m; t is the node reputation calculation time; parameter τ ($\tau = 2$) is used to control time decaying. $R(i \to j)^{t_m}$ is the on-chat reputation of node j reported by node i at time t_m, with afterwards voting $V_i^{j(t_m)}$ attached. If $V_i^{j(t_m)}$ is not provided by the node, we set $V_i^{j(t_m)}$ = 0.5. Note that $V_i^{j(t_m)} \in [0,1]$ and $R(i \to j) \in [0,1]$.

To get the general reputation of node j, denoted as $R(j)$, we aggregate all nodes' evaluation on it $\overline{R(i \to j)}$ based on Formula (3). The aggregation is weighted by the node's general reputation $R(i)$.

$$R(j) = \frac{f(K)}{W} \sum_{i=1}^{K} R(i) * \overline{R(i \to j)} \quad (3)$$

where, K is the total number of nodes who have direct experiences with node j. $W = \sum_{i=1}^{K} R(i)$ · $f(K) = \left\{1 - \exp(\frac{-K^2}{2(\sigma + \varepsilon)^2})\right\}$ is the Rayleigh cumulative distribution function to model the impact of K on node reputation, $\varepsilon = -K / K'$, is a factor to indicate sociability of node j. K' is the total number of users registered in the system.

Implementation

AdChatRep is implemented based on a pervasive social networking platform [1]. This platform provides an energy-efficient and fully distributed social networking environment. We develop MANET nodes using Nokia N900 with Python and GTK binding. The MANET communications are based on wireless LAN. The TS is implemented with Apache and PHP in Linux platform (Ubuntu 9.04).

AdChatRep supports both node-to-node chatting and community chatting. Any user can create a community by indicating the community name and its importance type (i.e., the crucial level of chatting topic) through the UI as shown in Figure 3. After creating a community, other people in vicinity can find the community in their device and join the community chatting. AdChatRep allows on-chat voting and visualizes reputation during chatting. Figure 4 shows a community chatting UI with personalized reputation visualization and on-chat voting with comments (e.g., "You DOWN Node 3: Too expensive".). Particularly, its user can select a preferred visualization scheme and active or deactive it. AdChatRep also provides detailed

information of on-chat and general reputations to its users by touching the 'eyes' icon in Figure 4 and the user photos.

Figure 3. Create a chatting community.

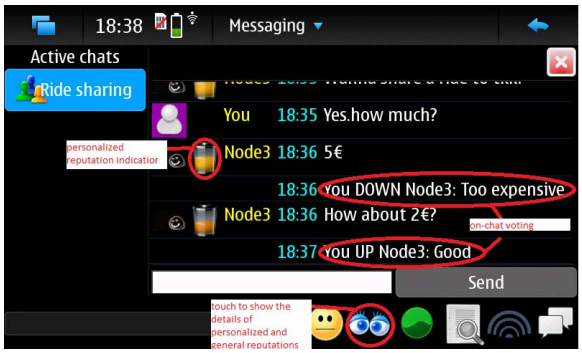


Figure 4. Community chatting UI and on-chat voting.

EXPERIMENTS AND RESULTS

Design

We performed a between-subject study to investigate the impacts of AdChatRep on mobile users. We selected 2 groups of participants from two student villages (each had 7 persons). All participants were university students aging between 23 and 28 years old. Among 7 participants in each group, 3 of them were female and 4 were male. They didn't know with each other. All of them had Internet chatting experiences, but none of them had experience on MANET chatting. Group 1 used AdChatRep during chatting whilst Group 2 did not (i.e., turned off reputation visualization).

We designed the experiment in a board game style in order to organize the study and make the results of two tests comparable. We asked the participants to simulate three chatting scenarios as described in our survey. Before the experiment, each participant got a card that indicates his/her roles and tasks in chat. The participants tried to make a decision with regard to their chatting purpose. For each scenario, they chatted in a community. During the tests, the chatting information, such as chatting time, contents, length, on-chat voting, and afterwards voting were automatically logged by AdChatRep for future analysis.

Additionally, we conducted an interview after the experiment to evaluate the perceived usefulness, perceived ease of use, interface, playfulness and user attitude in terms of AdChatRep. The participants were asked to express their

Purpose	Interview Statements
Perceived ease of use	Q1: It is easy for me to start chatting with a person I don't know.
	Q2: It is easy for me to make a decision during chatting.
	Q3: It is easy for me to select a person I like from many candidates during chatting.
Perceived Usefulness	Q4: AdChatRep can indicate user's reputation appropriately during chatting.
	Q5: AdChatRep assists my decision on social networking during chatting.
	Q6: AdChatRep is a useful and helpful application.
Interface	Q7: Reputation visualization during chatting is useful.
	Q8: AdChatRep has a good design on reputation visualization.
	Q9: AdChatRep has a good design on reputation explanation.
	Q10: AdChatRep has a good design on user interface.
Playfulness	Q11: AdChatRep is an interesting application.
Attitude	Q12: I like using AdChatRep.

Table 3. Interview statements.

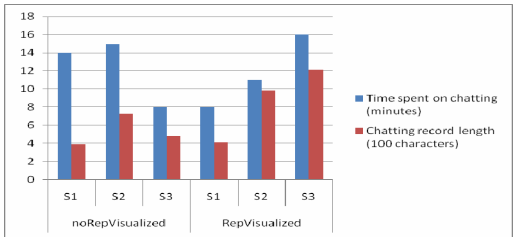
agreement on the statements listed in Table 3. The participants in Group 2 only responded Q1-Q3. A 5-point Likert scale was applied. Our interview was designed based on the TAM model (Technology Acceptance Model) and its extension, which indicates that usefulness, ease of use and playfulness lead to user acceptance [14, 15]. This theory also indicates that good interface leads to better perceived usefulness and ease of use; playfulness causes better acceptance (attitude). Finally, we randomly talked to some participants in order to get their additional comments. After the test, each participant was awarded a movie ticket.

Results and Implications

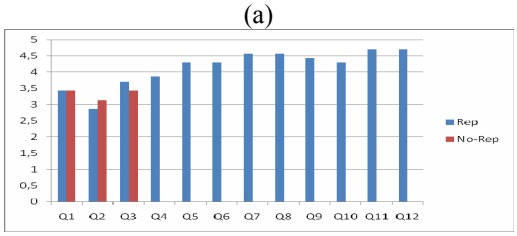
Investigating the chatting time and length, we observe from Figure 5a that displaying reputation information could encourage participants to chat more and become more social (refer to chatting record length), and help them chat in a more efficient way (i.e., chatting time was shorter) than the situation without displaying reputation. We also note that participants became more serious and took longer time to make a decision in a more crucial chatting scenario (e.g., Scenario 3 - car riding), when the reputation value is visualized (refer to chatting time).

As shown in Figure 5b, AdChatRep has satisfactory evaluation scores with regard to perceived ease of use, perceived usefulness, interface, playfulness and user attitude. We got high average scores (>4.0) for Q5-Q12. In terms of perceived ease of use, we notify that visualizing reputation in MANET chatting made participants easier to select a person they like from many candidates during chatting than without reputation visualization. The result showed that AdChatRep is a very useful and interesting (playful) application that can aid users' decision in MANET

chatting. Its UI (especially reputation visualization) got good feedback from the participants. They liked using AdChatRep. Based on the TAM, we can conclude that AdChatRep was well accepted by the participants.



(a)



(b)

Figure 5. (a) Chatting time and record length; (b) Average rates of interview statements.

In addition, the random talks provided us interesting implications: a) We found other potential use cases of AdChatRep such as dating and selling last-minute tickets at a concert hall; b) The user interface of chatting log navigation need to be improved, e.g., displaying chatting messages in an anti-chronological order. This is because the participants felt difficult to browse long chatting messages; c) Some participants regarded AdChatRep as a board game. They suggested extending AdChatRep to become a new platform for mobile gaming, where strangers nearby could play a game together.

CONCLUSIONS

We designed and developed AdChatRep driven by mobile users' needs. The paper contributes in four-folds: a) investigated how users consider and expect to cope with a reputation system for MANET chatting; b) designed and developed a usable reputation system for pervasive social networking, which is one of pioneer work in the literature; c) verified its usefulness and acceptance through a prototype based user experiment; d) tested the impact of introducing AdChatRep into MANET chatting with reputation visualization.

This work is still in its preliminary stage. Regarding the future work, we will test AdChatRep with regard to a number of system attacks in order to improve its robustness. In addition, we plan to do a trial to further evaluate its usefulness and user acceptance with statistical support.

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