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Content Sharing Over Smartphone-Based Delay-Tolerant Networks

Sk. Baji [1], Sk. Mastanvali [2]

[1] PG Scholar, Eswar College of Engineering, Narasaraopet, Guntur.
[2] Asst. Professor, Eswar College of Engineering, Narasaraopet, Guntur.

Abstract: *With the growing number of Smartphone users, peer-to-peer ad hoc content sharing is expected to occur more often. Thus, new content sharing mechanisms should be developed as traditional data delivery schemes are not efficient for content sharing due to the sporadic connectivity between Smart phones. To accomplish data delivery in such challenging environments, researchers have proposed the use of store-carry-forward protocols, in which a node stores a message and carries it until a forwarding opportunity arises through an encounter with other nodes. Most previous works in this field have focused on the prediction of whether two nodes would encounter each other, without considering the place and time of the encounter. In this paper, we propose discover-predict-deliver as an efficient content sharing scheme for delay-tolerant Smartphone networks. In our proposed scheme, contents are shared using the mobility information of individuals. Specifically, our approach employs a mobility learning algorithm to identify places indoors and outdoors. A hidden Markov model is used to predict an individual's future mobility information. Evaluation based on real traces indicates that with the proposed approach, 87 percent of contents can be correctly discovered and delivered within 2 hours when the content is available only in 30 percent of nodes in the network. We implement a sample application on commercial Smart phones, and we validate its efficiency to analyze the practical feasibility of the content sharing application. Our system approximately results in a2 percent CPU overhead and reduces the battery lifetime of a Smartphone by 15 percent at most.*

Keywords: *Smartphone, peer-to-peer, content sharing, traditional data delivery schemes, store-carry-forward protocols, mobile ad hoc network (MANET) routing protocols, Delay-Tolerant Network (DTN), Utility Computation, Mobility Learning.*

1. INTRODUCTION

Over the past few years, the number of Smartphone users has rapidly increased. as Smartphone interfaces are now convenient and user friendly, users can create various types of content. However, content sharing remains troublesome. it requires several user actions, such as registration, uploading to central servers, and searching and downloading contents. one way to reduce a user's burden is to rely on an ad hoc method of peer-to-peer content sharing. in this method, contents are spontaneously discovered and shared. the effectiveness of this sharing method depends on the efficiency of sharing and the significance of the shared contents. in this paper, we mainly focus on the efficiency of content sharing, and we provide suggestions on creating significant content. although ad hoc networks can easily be constructed with Smart phones as they are equipped with various network interfaces, such as Bluetooth and wi-fi, the connectivity between Smart phones is expected to be intermittent due to the movement patterns of carriers and the signal propagation phenomena. to overcome this problem, researchers have proposed a variety of storecarry forward routing schemes. in these schemes, a node stores a message and carries it for a certain duration until a communication opportunity arises. local forwarding decisions are independently made using utility functions, and multiple copies of the same message are propagated in parallel to increase the delivery probability. Therefore, delay-tolerant network (DTN) routing protocols achieve better performance than traditional mobile ad hoc network (MANET) routing protocols. the advantage of both DTN and MANET routing protocols is the absence of the requirement of a central server. hence, contents are distributed and stored directly on the Smart phones .

2. CONTENT SHARING

In this section, we analyze the problem of content sharing in Smartphone-based delay-tolerant networks and describe the solutions. As stated in the Introduction, we focus on store-carry-forward networking scenarios, in which the nodes communicate using DTN bundle architecture. Some Smartphones in the network store content that they are willing to share with others. All Smartphone users are willing to cooperate and supply a limited amount of their resources, such as bandwidth, storage, and processing power, to assist others. Our goal is to allow users to issue queries for content stored on other Smart phones anywhere in the network and to assess the chances of obtaining the information needed. We assume that Smart phones can perform searches on their local storage, and we find the relevant results for a given query to facilitate searching. Conceptually, the content sharing process is categorized into two phases: the content discovery phase and the content delivery phase. In the content discovery phase, a user inputs requests for content in a content sharing application. The application first searches for the content in local storage, and if not found, the application generates a query message based on the user’s request. The query is then spread in the network based on a specific forwarding decision and search-termination technique. When the content is found, the content delivery phase is initiated, and the content is routed toward the query originator.

3. EXISTING SYSTEM

One way to reduce a user’s burden is to rely on an ad hoc method of peer-to-peer content sharing. In this method, contents are spontaneously discovered and shared. The effectiveness of this sharing method depends on the efficiency of sharing and the significance of the shared contents. In this paper, we mainly focus on the efficiency of content sharing, and we provide suggestions on creating significant content. Therefore, Delay-Tolerant Network (DTN) routing protocols achieve better performance than traditional mobile ad hoc network (MANET) routing protocols.

Disadvantages of Existing System

- They mainly focused on limiting search query propagation and proposed a number of query processing methods. And not focus on the geographic search query propagation limit.
- Did not address the problem of indoor content sharing. Many routing protocols simply oversee the issue of obtaining location information indoors. In our work, we examine a network of Smart phones, with the consideration that Smartphone carriers spend most of their time indoors where GPS cannot be accessed.

4. PROPOSED SYSTEM

In this paper, we propose discover-predict-deliver (DPD) as an efficient content sharing scheme for Smartphone-based DTN s. DPD assumes that the communications between Smart phones arise in a set of locations where Smartphone carriers stay for a significant duration. It employs a hidden Markov model and Viterbi algorithm to predict the future locations of individuals.

The goal of our work is to explore the solutions to the content sharing problem in Smartphone-based DTN s. These solutions are the efficient discovery of contents and their delivery to the proper destinations within a given time.

Advantages of Proposed System:

- We develop a practical place (mobility) learning scheme for both outdoors and indoors. Also, we design a mobility prediction algorithm to accurately estimate the contact opportunities for Smartphone users.
- We evaluate the proposed scheme using simulation tools based on real human movement traces.
- We validate the feasibility of content sharing with DTN by implementing a sample application on commercial smart phones.

5. ALGORITHMS USED

Algorithm 1. Utility Computation

Algorithm 2. Mobility Learning

Utility Computation

Utility Computing is a service provisioning model in which a service provider makes computing resources and infrastructure management available to the customer as needed, and charges them for specific usage rather than a flat rate. Like other types of on-demand computing (such as grid computing), the utility model seeks to maximize the efficient use of resources and/or minimize associated costs. Utility is the packaging of computing resources, such as computation, storage and services, as a metered service. This model has the advantage of a low or no initial cost to acquire computer resources; instead, computational resources are essentially rented.

This repackaging of computing services became the foundation of the shift to "on demand" computing, software as a service and cloud computing models that further propagated the idea of computing, application and network as a service.

There was some initial skepticism about such a significant shift However, the new model of computing caught on and eventually became mainstream. IBM, HP and Microsoft were early leaders in the new field of Utility Computing with their business units and researchers working on the architecture, payment and development challenges of the new computing model. Google, Amazon and others started to take the lead in 2008, as they established their own utility services for computing, storage and applications.

Utility Computing can support grid computing which has the characteristic of very large computations or a sudden peaks in demand which are supported via a large number of computers. "Utility computing" has usually envisioned some form of virtualization so that the amount of storage or computing power available is considerably larger than that of a single time-sharing computer. Multiple servers are used on the "back end" to make this possible. These might be a dedicated computer cluster specifically built for the purpose of being rented out, or even an under-utilized supercomputer. The technique of running a single calculation on multiple computers is known as distributed computing.

Algorithm 1. Utility Computation
Input: Mobility Information $\mathbb{M}_d, \mathbb{M}_i$ Time t,
Remaining Content Lifetime T, Radio Range R
Output: Utility Function $U_i(d)$

$P_s \leftarrow 0; P_g \leftarrow \infty; w \leftarrow 0; k \leftarrow \lceil \frac{T}{\delta} \rceil$
$\mathbb{M}_d \Leftarrow \{l_{d,t}, l_{d,t+\delta}, \ldots, l_{d,t+k\delta}\}$
$\mathbb{M}_i \Leftarrow \{l_{i,t}, l_{i,t+\delta}, \ldots, l_{i,t+k\delta}\}$
for $m = t$ **to** $t + k\delta$ **step** δ **do**
  if $|l_{i,m} - l_{d,m}| \leq R$ **then**
    $P_s \leftarrow P_s + \frac{t}{m}$
  end if
end for
if $P_s \neq 0$ **then**
  $U_i(d) \leftarrow P_s$
else
  for $m = t$ **to** $t + k\delta$ **step** δ **do**
    if $|l_{i,m} + l_{d,m}| \leq P_g$ **then**
      $P_g \leftarrow |l_{i,m} - l_{d,m}|$
      $w \leftarrow m$
    end if
  end for
  $U_i(d) \leftarrow (-\frac{P_g}{R} \cdot \frac{t}{w})$
end if
return $U_i(d)$

Mobility Learning

In daily life, people typically visit a number of places, but not all of these are meaningful for earning people's mobility. Indeed, DPD requires the discovery of locations where content sharing can be performed. Content sharing is successfully performed in places where Smartphone users stay long enough, as perceiving the existence of other nodes and message exchanging requires several minutes depending on the size of the message, the bandwidth, and the network interface. Hence, we are basically interested in discovering places where the user stays longer than certain duration (i.e., meaningful places) and the context in user movement (i.e., paths).

Algorithm 2. Mobility Learning

Input: Stride Length γ, Last Location $l_{t}o$, Meaningful Places $\mathbb{L}$, Path Information $\mathbb{P}$

Output: Learning Meaningful Places and Paths

$t_0 \leftarrow Time; s \leftarrow 0; \vec{v}_t \leftarrow 0;$

$T_{stationary} \leftarrow 0; T_{moving} \leftarrow 0;$

while *true* **do**

  $\vec{v}_t \leftarrow$ *get accelometer readings*

  if $\mathcal{M}(\vec{v}_t)$ *is moving* **then**

    if $\vec{v}_t \geq \mu(\vec{v}_{t_0}, \ldots, \vec{v}_t) + \sigma(\vec{v}_{to}, \ldots, \vec{v}_t)$ **then**

      $s \leftarrow s + 1; \vec{v}_{t_p} \leftarrow \vec{v}_t$

      $T_{moving} \leftarrow T_{moving} + (t - t_0)$

      $T_{stationary} \leftarrow 0; t_0 \leftarrow t$

    end if

    if $T_{moving} \geq \delta$ **then**

6. EVALUATION

In this section, we first conduct parameter analysis, in which we evaluate the accuracy of the proposed scheme's core component: mobility learning and prediction. We also analyze the parameters of the proposed protocol to give suggestions on parameter selection. Then, we compare the performance of the content sharing with other works in terms of sharing efficiency, sharing latency, and cost. We collected user traces from four graduate students for eight weeks of their everyday lives. Each student was given an HTC Hero with Life Map installed and was requested to label the places he or she visited. In the experiment, a total of 908 meaningful places were learned and 1,923 APs were discovered. Fig. 1 shows the location of these meaningful places on the map (movement points are excluded) and the main area, in which we simulate our content sharing mechanism. Places are discovered in 15 km by 20 km area of Seoul, Korea.

7. PARAMETER ANALYSIS

We performed parameter analysis to validate the effectiveness of the employed mobility learning and prediction algorithm. We extracted a total of 172 annotated meaningful places, for which accurate physical locations were also provided, to analyze learning accuracy. Since all visits are separately recorded for these places (i.e., visits to similar places are not merged), both online and offline place matching (learning) could be applied. Learning accuracy and prediction accuracy are estimated on an HTC Desire Smartphone, and the rest of the parameter analysis is performed on a desktop computer using MATLAB.

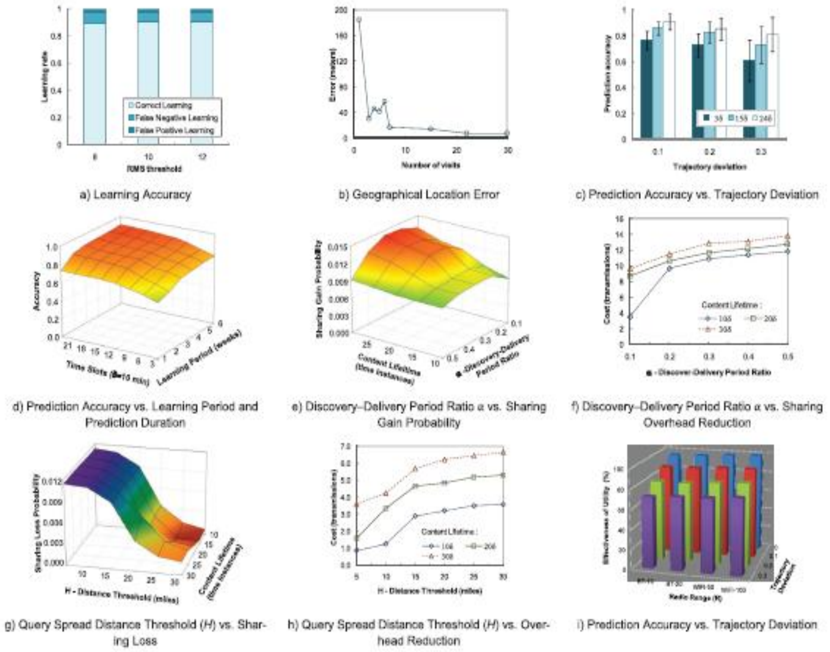


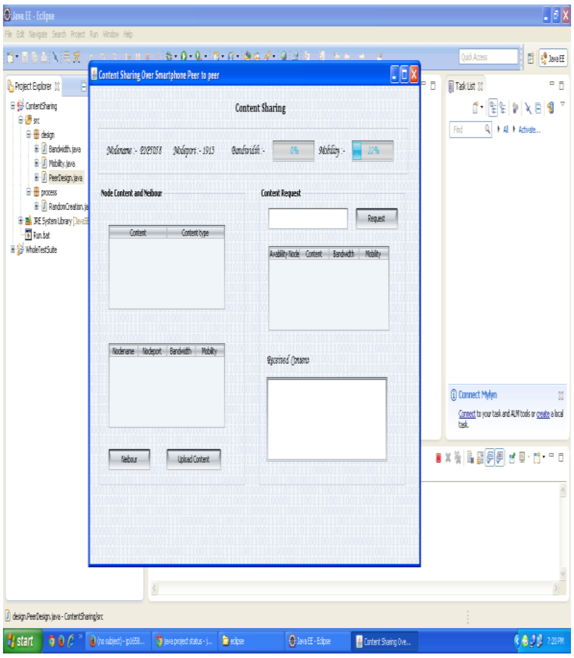
Fig.2. *Parameter analysis. The time instance _ is 10 minutes.*

In Fig. 2a, learning accuracy was measured according to various RMS thresholds. Here, "correct learning" means the algorithm correctly matched the candidate place with an existing place, and "false positive matching" means the proposed algorithm identified a candidate place to be the same as some existing place, although the places were different. Further, "false negative matching" means the algorithm identified a candidate place to be different from existing places, although there was a place considered Fig. 1. Collected meaningful places and the simulation area the same as the candidate place. The learning accuracy was above 90 percent, which shows that the proposed content sharing scheme is adequate. The accuracy generally increases as the RMS threshold increases. As shown in Fig. 2b, we measured the physical location error by comparing the estimated location with the actual location. As the number of visits increased, the location error was reduced. When a Smartphone user visits a place more than 20 times, the location error for the place becomes below 20 meters.

8. Implementation Analysis

An application for Smart phones should exhibit the following characteristics in order to be pragmatic: lightweight in terms of CPU and memory overhead, and efficient in resource utilization and energy consumption. Specifically, ad hoc content sharing applications should be carefully designed as such applications have to continuously run in the background. With the following experimental analysis, our goal is to identify the feasibility of content sharing applications on Smart phones. As described in Algorithm 2, mobility learning involves a sequence of jobs: location estimation, place similarity estimation, and so on. Although path update and place learning produce a high CPU overhead, their runtime is very short. Fig. 6b shows that the path update runtime is less than a second, and place learning takes about 10 seconds. Here, the place similarity match is tested for about 150 places. Mobility prediction generates a 9 percent CPU overhead and runs for about a second. In content creation, the application searches the database for matching contents, sorts the results according to downlink speed, and selects a set of hotspots that best satisfy the user request. Content creation has a 10 percent CPU overhead and runs for 2 seconds per request. In fact, the overhead of the content exchange task depends on the sizes of the content and mobility information. In this analysis, we experiment on 20 hotspot data with five APs per hotspot, and mobility information for an hour. Bluetooth radio interface is used to exchange contents among Smart phones. The content exchange produces a larger overhead and runs for a longer duration than other tasks because the content exchange requires mobility information exchange and utility computation. Still, the overhead is acceptable because the number of content exchanges is significantly reduced using the proposed DPD routing.

9. Screen Shot



10. Conclusion

In this paper, we proposed an efficient content sharing mechanism in Smartphone-based DTN s. We attempted to utilize the advantages of today's Smart phones (i.e., availability of various localization and communication technologies) and appropriately designed the protocol. In designing a content sharing algorithm, we focused on two points: 1) people move around meaningful places, and 2) the mobility of people is predictable. Based on this proposition, we developed a mobility learning and prediction algorithm to compute the utility function. Thus, in contrast to conventional methods, the proposed sharing mechanism does not require contact history. We learned that contents indeed have geographical and temporal validity, and we proposed a scheme by considering these characteristics of content. For example, distributing queries for content in an area 20 miles from the location of the content searcher has only a 0.3 percent chance to discover the content while generating 20 percent extra transmission cost.

Also, the time limitation on query distribution reduces transmission cost. Most important, the proposed protocol correctly discovers and delivers 87 percent of contents within 2 hours when the contents are available only in 30 percent of nodes in the network. The implementation of our system on Android platform indicates that the scheme results only in a 2 percent CPU overhead and reduces the battery lifetime of a Smartphone by 15 percent at most. Finally, we believe our system still has room for improvement. Specifically, the use of asymmetric multi core processors and efficient sensor scheduling is needed to reduce the energy consumption of Smart phones' sensors. Further, since location is the key element of the proposed solution, user privacy should be carefully considered. We plan to address these issues in our future works.

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AUTHORS' BIOGRAPHY

Sk. Baji is a M.Tech(CSE) pursuing student in Eswar college of Engineering, Narasaraopet, Guntur

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Sk.Mastanvali M.Tech in Computer Science & Engineering. He is presently working as an Asst. Prof. in Eswar College of Engineering, Narasaraopet, Guntur, India. He is having about 05 years of teaching experience in different Engineering Colleges.