Probability Model and Replica Allocation Methods in a Multimedia Mobile Learning System

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Abstract-Although various mobile learning related topics have been studied, a formal model to evaluate the probability of successful courseware media access in multimedia mobile learning systems has not yet been seen in the literatures. In this paper, we proposed a ***MAP*** (media access probability) model to evaluate the successful probability of course materials access. Also, the study of media allocation with replication is important in improving the media access probability. We can mine the moving patterns and media access patterns from moving logs to predict where he may go and what he may need in his next move. Based on the probability model, media access patterns and users moving patterns, the ***SRAM*** (static replica allocation method) and ***DRAM*** (dynamic replica allocation method) are presented to improve the media access probability.

Keywords: Mobile learning, probability model, replica allocation methods.

1. Introduction

The convergence of mobile communications and mobile computing devices offers the opportunity to develop a mobile teaching and learning environment. Fig. 1 shows the network architecture of a multimedia mobile learning system. For a multimedia mobile learning system, we can use a structured graph to model it no matter what the communication links are wired physical links or wireless radio links. The node set V represents the fixed media servers or mobile hosts. The edge set E represents the wired or wireless access path between two nodes. Figure 2 is an illustrated example.

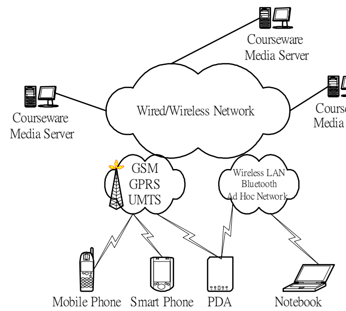

Fig. 1. The network architecture of a multimedia mobile learning system.

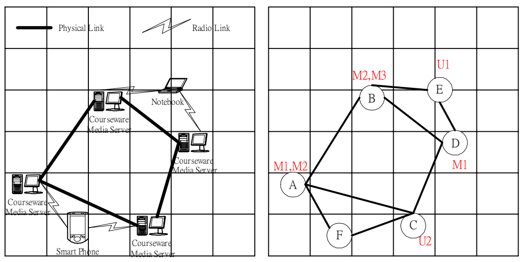

Fig. 2.(a) A network example of a multimedia mobile learning system. **2.(b)** The graph model of the network in Fig. 2.(a)

Once the mapping of the network architecture into a structured graph topology is done, we will propose a ***MAP***(media access probability) model to evaluate the probability of successful media access in a multimedia mobile learning system.

With the mining results of mobility patterns and media access patterns, one can replicate the needed media in advance to increase the successful probability of media access. In this paper, we present

SRAM (static replica allocation method) and ***DRAM*** (dynamic replica allocation method) to improve the media access probability. Examples are shown and elaborated to demonstrate the applicability of the proposed algorithms.

The rest of the paper is organized as follows. In the next section, a survey of related research works is given. Section 3 describes our proposed probability model and gives an illustrated numerical example. Two replica allocation methods and illustrated numerical examples are presented in section 4. Section 5 demonstrates the efficiency of the proposed replica allocation methods through a simulation study. We provide concluding remarks in section 6.

2. Related Work

In the literatures, most papers focus on the project design and implementation of a mobile learning system [1, 2]. Several papers have been addressed upon issues of data allocation in mobile computing systems [3, 4, 5]. Peng and Chen [5] proposed a data mining algorithm which involves incremental mining for user moving patterns and exploit the mining results to develop data allocation schemes for personal data and shared data. However, there are two limitations in [5]. First, only one data item is considered each time no matter for personal data or shared data. In this paper, many kinds of different courseware media can be accessed simultaneously for mobile users. Second, the considered performance criterion in [5] is the hit ratio that the user can access the required data only at the local node. But, except for the local node, the mobile users can also access the courseware from all connected remote nodes by all possible routing paths. Both the local and remote media access will be considered in our probability model.

Hara [4] proposed some methods of replicating data items on mobile host to improve data accessibility. The mobile host can access the needed data items from any connected mobile hosts with the data items replicated in it. However, the successful probability may be different to access the data items from local or remote nodes. This is not discussed in [4]. Moreover, Hara supposed that every node can replicate any data item in its memory. But, in a real mobile learning system, some media servers may be static and some private mobile hosts may disagree to replicate any other media in it. Both of the above considerations will be studied in our proposed replica allocation methods.

3. Media Access Probability Model

In this section, we propose a ***MAP*** (Media Access Probability) model to evaluate the probability of successful courseware media access in a multimedia mobile learning system.

3.1 Probability of a Communication Link Works

The communication links may be wired physical links or wireless radio links.

3.1.1 Operational Probabilities of Physical links. In Lin and Chen [6, 7], the reliability of a communication link is fixed as a constant during the modeling in a distributed computing system. We use a simple linear regression model to capture the dynamic behavior of the operational probability that the link can work well under different traffic load in this model.

3.1.2 Operational Probabilities of Radio Links. For a wireless radio link, we can use the measurement of the received signals (RSSI) from each neighbor to represent the operational probability of the radio link [8].

3.2 Probability of a Communication Node Works

Although any communication node may be failed at some time, we may assume that all the nodes are perfect. This assumption seems to be unrealistic. However, we can use a simple transformation to transform the node failure rates into a graph with flawless nodes and failing edges [9, 10].

3.3 Media Access Probability

The media access probability is defined as the probability that the needed media can be accessed successfully from all connected nodes by all possible routing paths. A ***MST*** (media spanning tree) is a tree that connects the user node to some other nodes such that its vertices hold all required media. And a minimal media spanning tree (***MMST***) is a tree such that no other MST which is a subset of the MMST exists. There may be many such MMST, and at least one of these media spanning trees must be operational in order to complete the courseware presentation request. In this paper, we use a FREA algorithm proposed by Lin and Chen [7, 8] to evaluate the probability that at least one of the minimal media spanning trees will work.

Numerical Example: Consider a wireless network that can be modeled by the graph in Fig. 3(a). Mobile user 1 is resident at node V_3. Media 1 is allocated at nodes V_1 and V_4. Media 2 is allocated at nodes V_1 and V_2. Media 3 is allocated at nodes V_2. Mobile user 1 needs media 1 and media 3 to complete the media access. Fig. 3(b) shows all the minimal media spanning trees to get the required media.

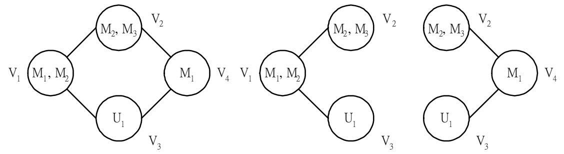

Fig. 3.(a) A 4-node network architecture.
(b) The minimal media spanning trees to get the required media.

Without loss of generality, we assume that all the links' operational probabilities are 0.9. Let E_1 = (V_3, V_1, and V_2 are connected), and E_2 = (V_3, V_4, V_2 are connected). Then, we can get the media access probability for mobile user 1 by conditional probability as follows: $MAP(U_1) = Prob((E_1) \text{ OR } (E_2)) = Pr(E_1)+Pr(E_1^c|E_2)*Pr(E_2)=0.9*0.9+(1-0.9*0.9)*0.9*0.9 = 0.9639$.

When the mobile user moves to another node, the requested media change, or due to the dynamic network topology, the media access probability will be different. We can partition the time dimension into several time slots. Each time any of the above factors change, we will recalculate the media access probability. We use the mean value of the several media access probabilities as the *MAP* for some specific mobile user. The mean value of the *MAP* for all mobile users in the system is defined as the system media access probability (s***MAP***). And then we use the s***MAP*** as the criterion to represent the performance of a mobile learning system.

3.4 Numerical Example

Consider a mobile learning system in Fig. 2. Mobile user 1 is resident at node E. Media 1 is allocated at nodes A and D. Media 2 is allocated at nodes A and B. Media 3 is allocated at nodes B. The resident nodes of the mobile user and the needed media at different time slots are shown in Table 1. We will derive the probability of successful media access according to the proposed model step by step.

3.4.1 Probability of a Communication Link works. Without loss of generality, we assume that all the links' operational probabilities are equal to 0.9.

3.4.2 Probability of a Communication Node works. We assume that all the nodes are perfect, i.e., with operational probabilities = 1.

Table 1 The Moving Path and Needed Media

Time slot	Resident node	Needed media
T_1	E	M_1, M_2
T_2	B	M_1, M_2, M_3
T_3	A	M_2, M_3
T_4	F	M_3
T_5	C	M_3

3.4.3 Media Access Probability. $MAP(U_1, T_1)$ = 0.9880461. $MAP(U_1, T_2)$ = 0.9981000. $MAP(U_1, T_3)$ = 0.9866125. $MAP(U_1, T_4)$ = 0.9766640. $MAP(U_1, T_5)$ = 0.9862876.

3.4.4 The System Media Access Probability. *sMAP* = $\sum(MAP(U_1, Ti))$ /5 = 0.98714204.

3.4.5 Another Allocation of Media M_3. If media M_3 is allocated at node D, the new *sMAP* will be 0.98674156.

This is smaller than the above probability. So, different media distribution will affect the successful probability of media access. In the following section, we will present two heuristic media replication methods to replicate media into appropriate locations such that the successful probability of media access can be improved.

4. Replica Allocation Methods

With the mining results of mobility patterns and media access patterns, one can replicate the needed media in advance to increase the successful probability of media access.

In order to capture the media access patterns and user moving patterns, the history moving logs are needed. For each mobile user, the time slot, resident node and the needed media are recorded in the log file such as in table 1. With such logs, we present ***SRAM*** (static replica allocation method) and ***DRAM*** (dynamic replica allocation method) to improve the *sMAP* in a multimedia mobile learning system.

4.1 Static Replica Allocation Method (*SRAM*)

Once the movement logs are generated, we can acquire the media access patterns by counting the access frequency of all media that are needed by some mobile user at some node.

Based on the media access patterns, we can replicate the media with highest access frequency first. The algorithm of the static replica allocation method (*SRAM*) is as follows:

Step 1: Use data mining techniques to get the media access patterns from the logs.
Step 2: For the node with memory space to replicate media, choose the media with highest access frequency first to be replicated.
Step 3: Discard the pattern record used in step 2.
Step 4: Repeat steps 2 and 3 until all nodes have no enough memory to replicate media.

4.2 Dynamic Replica Allocation Method

SRAM is a simple replica allocation method, but the user mobility patterns were not considered. Some circumstances must be considered due to the mobility characteristics. First, because the user may not always stay at some node, we should predict the next move to get the appropriate node to replicate the needed media. Second, there may be some media to be replicated to the same local node to achieve the maximum MAP for some individual mobile user. But what we concern is the system *sMAP* and the node capacity is not unlimited to replicate all media. So, we need to sort the order of media to be replicated according to some media importance measures. Third, several mobile users may want to access the same media at the same time slot. We have to replicate the media at the '*center*' of all the concerned mobile users. Here, '*center*' means the node that will cause a maximum system media access probability. That is, we must sort the order of media servers to replicate the media selected in the above step.

The algorithm of the dynamic replica allocation method (*DRAM*) is as follows:

Step 1: Use data mining and Markov chain techniques to get the moving patterns to predict the next move.
Step 2: Decide the replica allocation order of the needed media by the weights of the media.
Step 3: Decide the replica allocation order of the media servers by the all pairs maximum probability path algorithm.
Step 4: Replicate the minimum weight media first to the maximum probability node obtained in steps 2 and 3.
Step 5: Repeat until all media servers have not enough memory spaces to replicate any media.

4.2.1 Using Data Mining and Markov Chain Techniques to Predict the Next Move. If we can always replicate the needed media into the local node, we will have a maximum *sMAP*, i.e., 1. So, prediction of the mobile users' moving path will assist in the replica allocation. We use data mining techniques to capture the moving patterns from the movement log file. Based on the moving patterns, we use Markov chain to get the probability used as a basis to predict the next move.

4.2.2 Deciding the Replication Order of the Media. There will be some media to be replicated to the same node to achieve the maximum MAP for some individual mobile user. But what we concern is the system MAP and the node capacity is not unlimited to replicate all media. So, we need to sort the order of media to be replicated according to some media importance measures.

We define the weight of media i as follows. **W(Mi,Vj) = ∑(MAP(Vj,Mi))/n,** i.e., the mean value of the probabilities that all the users can access the media successfully from all possible routing paths. Our objective is to replicate the media to have a higher *sMAP*, so we should sort the media with the smallest weight to be replicated first.

4.2.3 Deciding the Order of Media Servers to Replicate the Selected Media. Once the media replication order is determined, we will consider where to replicate the media to achieve higher *sMAP*. If the media is needed by only one user at the time slot, we can replicate the media in the local node to have the MAP to be 1. If the memory space of the local node is not enough or the media is request by several users, we present the following algorithm to decide the allocation order of the nodes to replicate the concerned media. The algorithm can output a table showing the all pairs maximum probability path. There are many paths between two nodes to communicate. The probability of the path is the product of the operational probability of all the edges in the routing path. The maximum probability path is the path that has the maximum probability for the two nodes to communicate. If the media is needed by one user, we can replicate the media to the nodes ordered by the probability obtained in the algorithm in descending order. If the media is requested by several users, we sum the probabilities of the rows of the concerned users to represent the maximum probability path to the group users. And then, we can replicate the media according to the probability in descending order.

Algorithm: All pairs maximum probability path algorithm

Input: The network topology and the operational probability of each communication link

Output: All pairs maximum probability path

```
Begin
    for (k=1; k<=n; k++)
        for(i=1; i<=n; i++)
            for(j=1; j<=n; j++)
                P[i][j]= max(P[i][j] , P[i][k] * P [k][j] )
End
```

Example: Consider the network topology in Fig. 2. We assume that the operational probabilities of all communication links are equal to 0.9. We can use the above algorithm to calculate the all pairs maximum probability paths. Table 2 shows the results.

Table 2 All Pairs Maximum Probability Paths

	A	B	C	D	E	F
A	1	0.9	0.9	0.81	0.81	0.9
B	0.9	1	0.81	0.9	0.9	0.81
C	0.9	0.81	1	0.9	0.81	0.9
D	0.81	0.9	0.9	1	0.9	0.81
E	0.81	0.9	0.81	0.9	1	0.729
F	0.9	0.81	0.9	0.81	0.729	1

If media 1 is required by node A, C, and D, we sum the rows A, C, and D in table 2 to have the following data in table 3. So, Media 1 should be replicated on the ordering C, A, D, B, F, E.

Table 3 The Sum of Rows A, C, and D in table 3

	A	B	C	D	E	F
Sum(A,C, D)	2.71	2.61	2.80	2.71	2.52	2.61
Ordering	2	4	1	3	6	5

5. Simulation Experiments

We use a flatland to simulate the system in our model. There are some fixed media servers and mobile hosts in the plain. Each mobile host can moves randomly in all directions, and the movement speed is randomly determined. The radio communication range of each mobile host is a circle of radius R. Each medium i is held by media server i as the original.

Figure 4 presents the simulation results regarding *sMAP* evaluation of our proposed methods compared with no replication, and random replication methods. The results demonstrate the effectiveness of our proposed approaches.

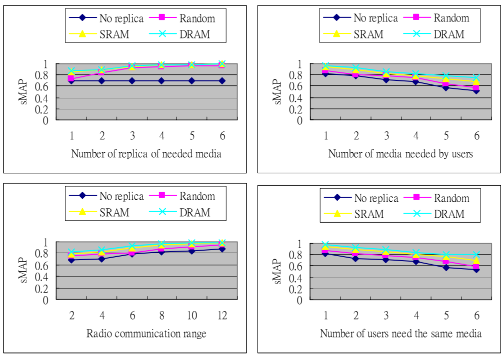

Fig. 4. Simulation results

6. Summary and Conclusion

In this paper, we proposed a ***MAP*** (media access probability) model to evaluate the successful probability of course materials access in a multimedia mobile learning system. Based on the media access patterns and mobile users mobility patterns, we also present ***SRAM*** (static replica allocation method) and ***DRAM*** (dynamic replica allocation method) to improve the media access probability. The proposed probability model and media allocation methods can be used as a network planning tool, and assist in the QoS provisioning of multimedia mobile learning systems.

Acknowledgements

This research was supported in part by National Science Council, MediaTek Inc., and Bestwise Inc.

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