

An Extended Payment Model for M-Commerce with Fair Non-Repudiation Protocols

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Abstract—Non-repudiation in e-commerce has recently gained a lot of interest but its successor brother, non-repudiation in m-commerce, is still at the start. In this paper, we propose an extension of existing mobile payment models to introduce an extended mobile payment service (EMPS) model, which is based on assumptions about the cooperation between mobile network operators and financial institutions to deal with different payment amounts ranging from micro to macro payment. The novel model focuses on enhancement of non-repudiation problem. Fair non-repudiation protocols are developed for not only payment phase but also other phases in a typical m-commerce transaction, including price negotiation and content delivery. Joint signatures method is used in protocols to overcome the limitations in mobile handheld device capability and to reduce the trust dependence totally on the payment service. As with the proposed non-repudiation protocols, EMPS plays the role of a semi-trusted third party and is an indispensable factor for creating the fairness property. Non-repudiation analyses of these protocols are also conducted besides some guidelines for ensuring non-repudiation in m-commerce.

Index Terms—Communication system security, M-commerce security, non-repudiation, semi-trusted 3rd party, payment model.

I. INTRODUCTION

IN recent years, *m-commerce* with many advantages such as the ubiquity, reachability, localization has emerged as a new potential application and research area. However, its inherently secure weaknesses, resulted from the limited capacity and the mobility of mobile handheld devices, insecure wireless channel, etc are the main obstacles on the path of success. Basically, security in m-commerce also deals with the fundamental issues as authentication and authorization, confidentiality, integrity, availability, and non-repudiation. Among these issues, non-repudiation, one of the services used to cope with internal attack risks, almost has not been studied thoroughly.

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Repudiation is the false denial of having been involved in a communication. The goal of the non-repudiation service is to generate, collect, maintain, make available and verify evidence concerning a claimed event or action in order to resolve disputes about the occurrence or non-occurrence of the event or action [12]. Currently, most non-repudiation protocols use digital signature in generating non-repudiation evidences. Among the properties of a non-repudiation protocol, fairness may be the most desirable. This feature helps the protocol execute fairly, i.e. at the end of the protocol, either both entities get the expected evidences, or none of them get any valuable information. Using a trusted third party (TTP) is a common approach to resolve this problem.

The power of non-repudiation services creates its importance to the commercial transactions in e-/m-commerce environments where the parties participating in may not trust each other. Non-repudiation in e-commerce has generated a lot of interests recently and built a relatively sound foundation while this issue in m-commerce is still at a start. Although m-commerce can be considered as mobile e-commerce, we can not apply the same non-repudiation protocols in e-commerce to the new environment because of the inherently insecure nature of wireless network and limited capability of mobile devices. Therefore, we need lightweight but sufficiently secure non-repudiation protocols to protect transactions conducted in wireless environment. Non-repudiation protocols in m-commerce should be based on existing non-repudiation protocols in e-commerce and adjusted to suit the resource constraints of mobile devices as well as specific requirements of different transaction types. Nearly all currently existing research mentioning the non-repudiation in m-commerce just pays attention to this problem in mobile payment, one of the most important commercial transactions in m-commerce. Mobile payment or billing is defined as the process of two parties exchanging financial value using a mobile device in return for goods or services [13]. A general mobile payment system, along with a typical transaction, is described in figure 1. It uses a third party which could act at the same time as a payment service provider and a TTP to support the financial transaction between mobile customer and service provider. As with m-commerce, none of the proposed solutions gives a complete analysis of non-repudiation properties such as non-repudiation evidences, the fairness property, the timeliness properties or a formal verification and so on. Moreover, some

forget the limited capability of mobile handheld devices while other solutions are suitable for only some specific cases.

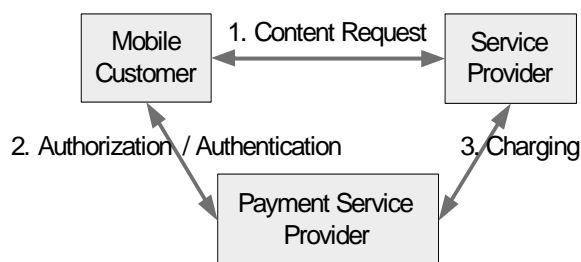


Fig. 1. A general mobile payment system.

In this paper, we propose a new mobile payment system founded on the extension of existing ones to support not only the non-repudiation protocol in the payment stage but also the other phases of a general commercial transaction such as price negotiation, content delivery, placing particular emphasis on the payment phase. In the proposed system, in addition to the traditional role, payment service provider also takes the role of a semi-trusted third party in non-repudiation protocols and supports mobile devices in generating non-repudiation evidences to help them overcome their limitations in computational power. The model and protocols proposed also address a variety of payment methods like credit card/account based payment methods, phone bill charging method and payment amounts like macro/micro payment.

The rest of this paper is organized as follows. Section 2 briefly discusses the related work. Section 3 presents common requirements and properties of non-repudiation protocols in m-commerce. In section 4, we introduce an extension of existing mobile payment systems, the overall architecture and innovations of our approach, and present three non-repudiation protocols for mobile transactions. Next, we carry out theoretical analyses of the proposed protocols in section 5. Finally, section 6 gives concluding remarks and presents future work.

II. RELATED WORK

There are several mobile payment models, ranging from the concept to universal model [2], and most of them do not refer to non-repudiation problems. Moreover, the other systems mentioning non-repudiation in their solutions either have too simple and inflexible models or give incomplete analysis and unsuitable non-repudiation protocols for m-commerce environment. Some typical previous work is discussed as follows.

- The limited models such as PayBox, Vodafone m-PayBill, iPIN [10] are restricted in payment methods, customer, secure mechanism and none of them provides non-repudiation protocols.
- SEMOPS [9] is a typical example of universal models. The model looks prettily perfect because it is capable of supporting all transactions values, operating in any

channels and supporting any transaction type with a domestic and/or international geographic coverage. However, SEMOPS does not give any formal protocols for its transactions and non-repudiation is not handled too. Another limitation of SEMOPS is that the customer and service provider have to trust the payment processor absolutely. Furthermore, using data center increases the number of steps in a transaction and reasonable solutions to traditional problems around data center such as bottleneck, attack risks are not presented.

- The payment model presented in [2] is derived from SEMOPS model with some enhancements for tackling the signature validating and privacy issues. A protocol which is a formal representation of the payment process and some initial non-repudiation analyses are discussed in [2]. This is a very first effort for non-repudiation in m-commerce, but the proposed protocol does not take into account the limited capacity of mobile devices when using traditional signatures to generate non-repudiation evidences and the non-repudiation analysis is just the case of non-repudiation of origin. Moreover, the given protocol skips the differences in nature of different payment methods and payment value.
- Other solutions to non-repudiation in mobile payment concerning evidence generation cost are given in [1, 3]. Both of them use the joint signature instead of traditional digital signature to reduce cost but one is for home network and the other is for foreign network. Although they are better than the aforementioned ones due to low cost, deeper non-repudiation analysis, they are only suitable for small payment which charges mobile customers through their phone bills.

III. NON-REPUDIATION CONSIDERATIONS IN M-COMMERCE

An m-commerce transaction taking place between mobile customer (MC) and service provider (SP) usually involves three phases: price negotiation, payment and content delivery. The non-repudiation requirements for this transaction include:

- *Non-repudiation in price negotiation phase*: MC and SP can not falsely deny having involved in the communication and agreed on the given price.
- *Non-repudiation in payment phase*: MC can not falsely deny having agreed to pay her bill and SP can not falsely deny having received the payment for the invoice of MC.
- *Non-repudiation in content delivery phase*: MC can not falsely deny having received goods and SP can not falsely deny having not delivered the goods.

By examining the existing non-repudiation protocols in e-commerce and specific properties of m-commerce like the limited computational capability, inherently insecure wireless network, we identify some requirements for building non-repudiation protocols in m-commerce:

- They should be built on the non-repudiation foundation in e-commerce.
- Number of messages originated from mobile customer should be minimized.

containing both $k_{mc,emps-mc}$ and $k_{mc,sp}$. EMPS of MC, which has large computational capability and also involves in the transaction between MC and SP, will sign on these messages to create the irrefutable evidences of non-repudiation protocols.

- A strong point of this model is the ability to reduce the trust dependence of MC to EMPS. In the system, EMPS can be regarded as a semi-trusted third party. This implies that EMPS just helps MC sign evidences and transfer them to other parties but it cannot modify or forge these evidences because of the presence of the secret key $k_{mc,sp}$, which is known only by MC and SP, in these evidences.

The system model of EMPS is shown in figure 2. There are four main parties participating in this model: MC, SP, EMPS-MC, and EMPS-SP. To gain the generality, we assume that MC and SP register to different EMPSs and these EMPSs trust each other. EMPS-MC and EMPS-SP are the payment service providers of MC and SP respectively. In our model, MNO collaborates with FI/B to build EMPS. While FI/B deals with macro payment, MNO is responsible for micro payment and supports MC in generating joint signature besides the traditional role of wireless access provider. In addition to these main parties, TSA and CA which are the essential TTP in most non-repudiation protocols also appear in our model. TSA is used to add trusted time information to evidence; and in the non-repudiation protocols, the step in which evidence is time-stamped is usually omitted for simplicity. CA is another TTP that issues public key certificates to guarantee the authenticity of public verification keys used for non-repudiation purpose.

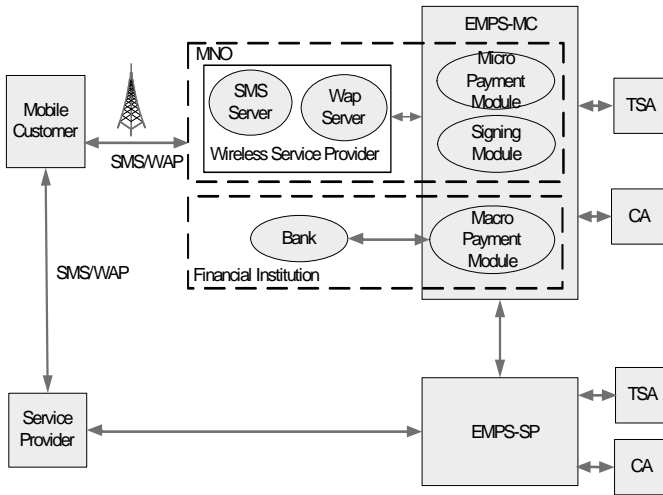


Fig. 2. EMPS System Model

Due to the space limitation, we just summarize main features of crucial modules in EMPS. Micro Payment Module handles micro payment and Macro Payment Module involves in macro payment. Signing Module helps MC generate joint signature on evidences and messages. Price Negotiation Module manages the related message in price negotiation

phase and Content Delivery Module deals with managing the related messages in content delivery phase. Another module is User Management Module which manages customers of EMPS. Customers of EMPS can be categorized into MC, SP and other EMPS. Therefore, we need some communication modules serving the interaction between MC and EMPS, SP and EMPS as well as between EMPSs. In order to facilitate customers' easy access to the services, EMPS also supplies the front-end modules to MC and SP, especially MC front-end module which can assist MC to carry out an m-commerce transaction with necessary functions such as price negotiation, payment, personalization, and security.

B. Fair Non-Repudiation Protocols of M-Commerce Transactions in EMPS

TABLE I
NOTATIONS.

$h(m)$	Collision resistant hash function
m_1, m_2	Concatenation of data item m_1 and m_2
$k_{A,B}$	Session key shared between A and B
ID_A	Identity of entity A
$pk_A=(e_A, n_A)$	Public key of entity A
$sk_A=(d_A, n_A)$	Private key of entity A
$s_A=(h(m))^{d(A)} \text{ mod } n_A$	Entity A signature over message m
E_k	A symmetric key encryption function under key k
D_k	A symmetric key decryption function under key k
$c=E_k(m)$	Cipher of message m under the key k
E_A	A public key encryption function under A's public key
D_A	A public key decryption function under A's private key
$cert_A$	Digital Certificate of entity A
L	A label uniquely identifies a protocol run
F	A flag indicating the purpose of a message
$y=HOAC$	Hash Origin Authentication Code
$x=HMAC$	Hash Message Authentication Code
ts_A	Time stamp of entity A
d_{A-P}	A deadline for response which is imposed by A in protocol P
$dl=[t_s, t_e]$	A time interval
OI	Order Information
P_A	Price suggested by entity A
PID	Identity of Product which MC intends to buy
N	Quantity of a Product which MC intends to buy
Adr_A	Delivery address of A
$Account_A$	Information about account of entity A
SC	Shipping cost

on the deal between 2 EMPSs. EMPS-MC charges MC through her phone bill and notifies MC of payment completion in step 5.

Macro Payment Protocol: In contrast to micro payment which is charged through phone bill, macro payment is paid by bank account or card. Therefore, this protocol will require some information involving in customer account or card. Some assumptions are made for this case. First, MC shares information about account or his card (AI) with the FI/B which issues the card or account of MC. The second assumption is that MC is also given a PIN shared between MC and FI/B only. When MC registers with EMPS-MC for macro payment service, she must supply information about her FI/B. The macro payment protocol is very similar to the micro payment protocol and the difference between them is slim. The first difference lies in the information sent to EMPS-MC in step 1. Besides the information like in step 1 in micro payment protocol, MC also sends z_{map} , a HOAC used to show FI/B that the request for payment is from MC. The other differences are found in the internal processes of EMPS-MC at step 2' and 5'. Prior to transferring the request for payment of MC to SP, EMPS-MC will examine the financial situation of MC by sending the OIResponse and z_{map} to FI/B (step 2'.1). FI/B of EMPS-MC will contact with the FI/B of customer to get information. This process happens under the banking private network. The result will be returned to EMPS-MC in step 2'.2. If the result is positive, EMPS-MC will proceed to the remaining steps like in micro payment. The last difference is in step 5'. EMPS-MC requires its FI/B to link to FI/B of MC to conduct the transaction. The result is returned to EMPS-MC in step 5'.2. The final step of this protocol is the same as step 5 in micro payment protocol.

1. MC → EMPS-MC: $f_{map}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, dl_{map}, ts_{mc}, d_{mc-map}, EK_{mc,sp}(OIResponse), y_{map}, x_{map}, z_{map}$
 $y_{map} = h(OIResponse, l, dl_{map}, k_{mc,sp}, d_{mc-map}, h(k_{mc,emps-mc}))$ is a HOAC indicating to SP that the original of the request for payment is from MC.
 $z_{map} = h(OIResponse, AI, dl_{map}, PIN)$ is a HOAC indicating to FI/B that the original of the request for payment is from MC.
 $x_{map} = h(OIResponse, ts_{mc}, k_{mc,emps-mc}, y_{map}, z_{map})$ is a HMAC showing EMPS-MC that the HOAC y_{map} and z_{map} are from MC.

2'. Inside EMPS-MC

2'.1. EMPS-MC → FI/B: $f_{map}, ID_{mc}, OIResponse, z_{map}, dl_{map}, d_{mc-map}, S_{emps-mc}(OIResponse, z_{map}, dl_{map}, d_{mc-map})$
2'.2. FI/B → EMPS-MC: $f_{map}, ID_{mc}, OIResponse, Result, s_{fi/b}(OIResponse, z_{map}, Result)$
 Result = Yes/No

2. EMPS-MC → SP: $f_{map}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, dl_{map}, ts_{emps-mc}, d_{mc-map}, E_{sp}(OIResponse), y_{map}, x_{map}, signmap_{emps-mc}$
 $signmap_{emps-mc} = S_{emps-mc}(f_{map}, l, dl_{map}, ts_{emps-mc}, d_{mc-map}, OIResponse, y_{map}, x_{map})$

3. SP → EMPS-SP: $f_{map}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, d_{mc-map}, E_{emps-sp}(Bill), s_{sp}(f_{map}, l, Bill, d_{mc-map})$
 Bill = OIResponse, Approval

4. EMPS-SP → EMPS-MC: $f_{map}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, E_{emps-mc}(Bill, Account_{emps-sp}), S_{emps-sp}(f_{map}, l, Bill, Account_{emps-sp})$

5'. Inside EMPS-MC

5'.1. EMPS-MC → FI/B: $f_{map}, ID_{mc}, OIResponse, dl_{map}, E_{fi/b}(Bill, Account_{emps-sp}), S_{emps-mc}(f_{map}, Bill, Account_{emps-sp})$

5'.2. FI/B → EMPS-MC: $f_{map}, ID_{mc}, OIResponse, dl_{map}, Result, s_{fi/b}(f_{map}, Bill, Result)$
 Result = Yes/No

5. EMPS-MC → MC: $f_{map}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, Ek_{mc,emps-mc}(Bill, Result), S_{emps-mc}(f_{map}, l, Bill, Result)$

Content Delivery Protocol

This protocol is based on the assumption that the content delivered is the electronic goods, for example software, music, films, financial report, and can be considered as a message m in general. If the content is physical goods, we can use the traditional delivery method such as transportation companies and there is no concern of the repudiation problem. The protocol is divided into three sub-protocols, a main, a recovery and an abort protocol. In case of problems, the abort or recovery protocol can be involved.

1. SP → MC: $f_{cd}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, c, E_{emps-sp}(Ek_{mc,sp}(k)), EOO_c$
 $EOO_c = S_{sp}(f_{cd}, l, c, E_{emps-sp}(Ek_{mc,sp}(k)))$

2. MC → EMPS-MC: $f_{cd}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, dl_{cd}, ts_{mc}, d_{mc-cd}, h(c), h(E_{emps-sp}(Ek_{mc,sp}(k))), y_{cd}, x_{cd}$
 $y_{cd} = h(dl_{cd}, h(c), h(EK), dl_{cd}, d_{mc-cd}, k_{mc,sp}, h(k_{mc,emps-mc}))$ is a HOAC indicating to SP that the response for cipher c is from MC.
 $x_{cd} = h(f_{cd}, l, ts_{mc}, h(c), h(EK), k_{mc,emps-mc}, y_{cd})$ is a HMAC indicating to EMPS-MC that the HOAC y_{cd} is from MC.

3. EMPS-MC → SP: $f_{cd}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, dl_{dc}, ts_{emps-mc}, d_{mc-cd}, h(c), h(E_{emps-sp}(Ek_{mc,sp}(k))), y_{cd}, x_{cd}, signcd_{emps-mc}$
 $signcd_{emps-mc} = S_{emps-mc}(f_{cd}, l, dl_{dc}, ts_{emps-mc}, d_{mc-cd}, h(c), h(E_{emps-sp}(Ek_{mc,sp}(k))), y_{cd}, x_{cd})$
If SP times out then abort

4. SP → MC: $f_{cd}, l, ID_{mc}, ID_{sp}, ID_{emps-mc}, ID_{emps-sp}, Ek_{mc,sp}(k), S_{sp}(f_{cd}, l, k)$
If MC times out then recovery

Main Protocol: SP sends the cipher of message and the evidence of origin for cipher EOO_c to MC in step 1 and waits for the non-repudiation of receipt evidence NRR. If MC carries out the step 2, the step 3 must be executed because EMPS-MC is a trust party of MC. So we can consider step2

Fairness: The protocol is strong fairness. If the step 2-3 of main protocol is not executed, SP can invoke the abort protocol and no party can obtain correct evidence anymore. If MC launches a recovery protocol, both MC and SP will receive all expected evidences, and hence the protocol remains fair.

Timeliness: Timeliness is provided by the fact that at each moment in the protocol, both MC and SP can stop the protocol while preserving fairness.

V. CONCLUSIONS AND FUTURE WORK

In this paper we have identified the most common requirements and properties of concern for dealing with non-repudiation problem in m-commerce. Then, we have introduced an extension of mobile payment model named EMPS for solving the above problem. Based on the EMPS, three non-repudiation protocols for *all fundamental phases* (price negotiation, mobile payment, content delivery) in m-commerce transactions have been built. To the best of our knowledge, this holistic approach to the non-repudiation problem in m-commerce is among the vanguard solutions to address it. Analyses of the non-repudiability, fairness and timeliness of the proposed protocols are also carried out. They are the solid basis for our further improvements in the future.

In the future, we plan to standardize communications among parties in EMPS model, especially between MNO and FI/B and among EMPSs. Web service standard is one of our targets for this purpose. Additional formal analyses along with improvements to achieve the timeliness of the proposed non-repudiation protocols will be of our great interest. Moreover, generating long-term key from session key, combining the initiation process with price negotiation process, etc. are also of our concerns. We also intend to perform empirical evaluations on the proposed protocols' performance to establish their practical value.

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