

OpenPGP-based Financial Instruments and Dispute Arbitration

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Abstract. In this paper, we present some guidelines for implementing various financial instruments for the purposes of credit and payment, including protocols for commercial transactions, dispute resolution, and establishing credit reputation. We strive to employ only widely used, standardized cryptography and keep the proposed procedures as simple as possible on the conceptual level. Also, we want all the documents to resemble their paper-based counterparts as closely as possible and be readable by humans, while also facilitating automated processing by computers. The presented results are being actively implemented within the ePoint System framework.

1 Introduction

Electronic commerce is currently severely hampered by the lack of reliable financial and legal services matching the speed and convenience of on-line transactions. When online contracts are made by filling out and submitting web forms (with no customer copy beyond an easily forgeable confirmation email) and payment authorization is done by entering one's credit card details, all involved parties are highly vulnerable to fraud. In case of such fraud, especially in an international setting, legal proceedings are prohibitively slow and expensive and fraught with inconsistent rulings due to the lack of reliable evidence.

The problems resulting from the lack of common jurisdiction, ill-equipped central authorities and impracticality of coercive enforcement of contracts are nothing new; international trade has always been beset by such problems [4, 5]. The body of laws and customs for international trade, commonly known as *Lex Mercatoria*[3, 8], provides us with both inspiration and guidance for designing a set of on-line protocols for overcoming the above described difficulties in electronic commerce. In this paper, we describe some core techniques and procedures

concerning financial instruments used for payment and credit that rely as much as possible on the existing infrastructure.

OpenPGP[1] is the IETF standard inspired by Phil Zimmerman's PGP program that, among other things, describes digitally signed documents and facilities for peer-to-peer certification of public keys. Over time, a distributed, decentralized, massively redundant network of so-called Public Key Servers (PKS) has been established, based on Mark Horowitz's web- and email-based protocol (HKP[2]). At the time of writing, the peer-to-peer certification facility and the PKS network is used solely for establishing bindings between public keys and identities and the trustworthiness of participants in such matters, forming the so-called PGP Web of Trust. However, as shown in this paper, this infrastructure can be leveraged for the purpose of the more general task of reputation tracking. In particular, for recording and disseminating arbitrator decisions and other information affecting credit reputation.

Our goal is to design procedures that can be easily understood by the Internet-using public. In particular, we would like to avoid relying on "exotic cryptography" that is conceptually difficult to grasp. Instead, we rely on third parties that require only very limited trust (e.g. PKS servers, time stampers, etc.). Also, we often forfeit the ability to prevent fraud by making it infeasible; instead, we deter it by reactive security measures made possible by strong evidence in the spirit of *Lex Mercatoria*.

2 Electronic Evidence

Unfortunately, *Lex Mercatoria* is often not applicable directly to electronic commerce, because many of its implicit assumptions break down on the Internet. Also, in many cases, contemporary telecommunications allow for short-cuts and considerable improvements in efficiency over customary practices.

Traditionally, documentary evidence is the result of marking paper with ink. Once the paper is marked, it is very difficult to remove these marks as if they have never been there and it is often also difficult to make an exact duplicate of the unmarked document. With electronic documents, this is not the case; any change to a document can be reversed with minimal effort, precisely by the way of keeping an exact duplicate of the unmarked version, which is practically free. This problem alone renders large parts of *Lex Mercatoria* inapplicable to electronic transactions, at least directly.

Instead, in the digital world, the irreversible operation is revealing information that was not previously known [11]. It is very costly to force someone to forget a piece of information and it is even more problematic to completely erase something from the public records. Conveniently, PKS infrastructure provides us with straightforward means to irreversibly publish pieces of information.

The above implies that digital signatures cannot, in a legal sense, be always treated as digital equivalents of pen-and-paper signatures[9] or even seals[10] (with which they actually have more in common, as a seal can be stolen just like a private key). There is a qualitative difference between the two, limiting

the usefulness of the metaphor. Instead, digital signatures should be treated as an integrity protection mechanism; evidence witnessed by the signer that the document has not been altered by unauthorized parties.

3 Digital Representations of Debt and Credit Reputation

3.1 General Negotiable Financial Instrument

Traditionally, negotiable instrument is generally defined as a transferable, signed document that unconditionally promises to pay the bearer a sum of money at a future date or on demand. Negotiable instruments are commonly used in business transactions to finance the movement of goods and to secure and distribute loans. Examples include cheques, bills of exchange, and promissory notes. All of them have statutory requirements that define their main elements, and these should be strictly fulfilled. It is also important to emphasize that there is a number of similar financial instruments, such as letters of credit that are treated separately by law and custom, which, nevertheless, can be represented digitally in a very similar way[6, 7].

In addition to their paper-based equivalents, digital instruments must include a cryptographic challenge corresponding to a secret known to the bearer of the instrument. Endorsements must include a proof of knowledge of this secret (typically, the secret itself) and a new challenge corresponding to a secret known to the new bearer. Technically, revealing such a secret invalidates the instrument; endorsements are, in fact, back-to-back instruments carrying the same promise. The exact legal interpretation will hopefully emerge from future precedents.

It is possible to turn these instruments into smart contracts [12], that are automatically processed by suitable machinery. We believe that this approach has some very important benefits over expressing smart contracts in universal programming languages (even specialized ones, such as E [14]), such as limiting the possibility of obfuscation and being generally readable to non-programmers.

3.2 General Reputation Record

A rarely used feature of OpenPGP called “notation data” embedded in signatures (only available since version 4) allows OpenPGP users to make elaborate statements about themselves and one another. It can be used in combination with another rarely used (and only partially implemented) feature: signatures made directly on the public key of the subject (tag 0x1F, see Section 5.2.1. of [1]), which make it impossible for the subjects to get rid of these statements without discarding their entire digital identity and reputation.

Such statements can be disseminated (reliably and irreversibly) using the existing PKS infrastructure. All the techniques that have been developed (and already implemented) for judging the reliability of statements about the identities corresponding to public keys can be directly applied to statements about their creditworthiness, with relevant information written into notation data.

4 Arbitration

In this section, we outline the arbitration protocol, with Alice being the claimant, Bob the respondent and Justin the arbitrator.

First, Alice sends a claim against Bob to Justin, *including* evidence supporting her claim and a digital invoice (payable by Bob) for the value claimed. After receiving it, Justin invoices Alice for the arbitration fee. This invoice refers to Alice’s statement of claim by hash value.

Once the fee is paid, Justin notifies Bob, presenting him with Alice’s claim and the supporting evidence. This is done automatically, without human intervention.

Bob, at this point, has four options:

1. He can *settle* by paying Alice the claimed amount; this would be evidenced by a signed transaction record containing the same cryptographic challenge and value as Alice’s statement of claim.
2. He can *contest* Alice’s claim. At this point, he should also present Justin with evidence proving Alice’s claim wrongful. Justin acknowledges receiving Bob’s documents in a signed receipt, referring to each document and Alice’s statement of claim by hash value.
3. Bob may also *demur* at Alice’s claim. This means that Bob is not contesting any of the factual statements, but informs Justin that in his view they do not imply that Bob should pay anything to Alice. It is the formal way of saying “so what?”. The demurrer is a document signed by Bob referring to Alice’s statement of claim by hash value. Justin acknowledges receiving Bob’s demurrer in a signed receipt with the corresponding hash value.
4. Bob may *do nothing* within the time frame allotted for responding to Alice’s claim.

The consequence of the first choice is that the case is closed. Clearly, from Justin’s point of view, this is the most desirable outcome, as he ends up pocketing the arbitration fee, without using human resources.

In the second case, Justin proceeds with evaluating the available evidence. Depending on its nature, the process can be automated to some extent. In some cases it can be even fully automated. If Alice’s claim does not stand up, both Alice and Bob get notified about the case being closed. If Justin finds Bob in the wrong, then Bob is invoiced for damages and arbitration. If he fails to pay this invoice on time, then Alice shall receive a demerit signature of Justin on Bob’s key, which she is free to upload to the PKS network.

In the third case, Justin decides on the demurrer assuming that the factual statements in Alice’s claim are true. Otherwise, however, the demurrer is *not* an admission of those facts by Bob. If the demurrer is sustained, both parties receive a signed statement to this effect from Justin and the case is closed. If not, the case proceeds as if Bob decided to do nothing. The reason for using the largely obsolete demurrer is that its use results in possibly crucial evidence for other arbitration procedures connected to the one in question, such as appeals or disputes further up the endorsement chain of some negotiable instrument.

The consequences of the fourth choice (doing nothing) also depend on the particular case. In general, Bob should not be encouraged to delay arbitration by doing nothing, but on the other hand Bob should be protected from harassment.

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A server program processing various financial instruments is described in detail in Janis Schuller's thesis [13]. This piece of software will be the basis for the reference implementation of the protocols and data formats used for procedures described above.

For a detailed discussion with examples, please see the full version of this paper available online at <http://www.epointsystem.org/~nagydani/fc2008.pdf>

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