Blockchain Based Accounts Payable Platform for Goods Trade

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***Abstract*—Goods trade is a supply chain transaction that involves shippers buying goods from suppliers and carriers providing goods transportation. Shippers are issued invoices from suppliers and carriers. Shippers carry out goods receiving and invoice processing before payment processing of bills for suppliers and carriers, where invoice processing includes tasks like processing claims and adjusting the bill payments. Goods receiving involves verification of received goods by the Shipper's receiving team. Invoice processing is carried out by the Shipper's accounts payable team, which in turn is verified by the accounts receivable teams of suppliers and carriers. This paper presents a blockchain-based accounts payable system that generates claims for the deficiency in the goods received and accordingly adjusts the payment in the bills for suppliers and carriers. Primary motivations for these supply chain organizations to adopt blockchain-based accounts payable systems are to eliminate the process redundancies (accounts payable vs. accounts receivable), to reduce the number of disputes among the transacting participants, and to accelerate the accounts payable processes via optimizations in the claims generation and blockchain-based dispute reconciliation.**

***Index Terms*—Goods trade, accounts payable, invoice processing, dispute management, blockchain, smart contract**

I. Introduction

Any trade transaction, be it domestic or global, involves exercising certain processes to complete. Domestic trade is the exchange of goods within country boundaries in contrast to between different countries in global/international trade.

We describe the different processes involved in goods trade using a global trade transaction in figure Fig. 2. *Shippers* initiate a trade transaction by sending a *purchase order* (PO) which consists of details of the requested goods to the *suppliers*. Suppliers typically package the goods into intermodal containers either by themselves or with the help of *Origin Cargo Management (OCM)* team. Suppliers issue *dispatch advice* (DA) that describes the goods packed details, and *commercial invoice* (CI) that describes the terms together with the details of the amount that shipper must pay for the goods supplied. Since global trade involves freight transportation across country borders, a typical freight journey involves multiple modes (e.g., road, rail, or sea) of carriers contributing to the container movement from origin to the destination. Moreover, freight transportation may also involve *drayage* providers to move containers a short distance via ground freight (e.g., move containers from truck to a ship).

Once freight reaches the delivery center at destination, the goods receiving team of the shipper verifies if the received goods can be accepted or not. If there are any damages to the received goods or discrepancies in terms of received quantity/price against PO, then the receiving team records the same via *receiving advice* (RA). The different carriers involved in freight movement also issue their respective invoices for their services. Once the shipper has access to invoices of carriers and the supplier, its accounts payable team needs to process the invoices. First, the accounts payable team raises a claim for the discrepancies reported in RA in the form of *claim advice* (CA). Second, the accounts payable team deducts the amount captured in CA from the appropriate invoice (either from the supplier's invoice or from a carrier's invoice whoever is accountable) and generate *payment advices* (PAs), where each PA captures the net amount payable by the shipper either to the supplier or to a carrier.

Payment processing involves executing a payment method as per the terms captured in the service contracts between trade participants. The most common payment method is *open account*, where the goods is shipped and delivered before the release of funds from the shipper within an agreed time frame. There is another payment method which involves *financing* facilitated by banks and financial institutions (e.g., *letter of credit* [1] for supplier invoices in global trade, *factoring* [2] for carrier invoices in global trade, and *reverse factoring* [3] for supplier invoices in domestic trade). Goods trade can be summarized as the shipper acquiring the goods by paying the bills to the supplier and carriers as captured in figure Fig. 2.

The sequence of processes that get exercised during goods trade is captured in figure Fig. 1. Different business documents are communicated among the transacting parties electronically in standard document formats known as *Electronic Data*

* The author contributed during his association with IBM

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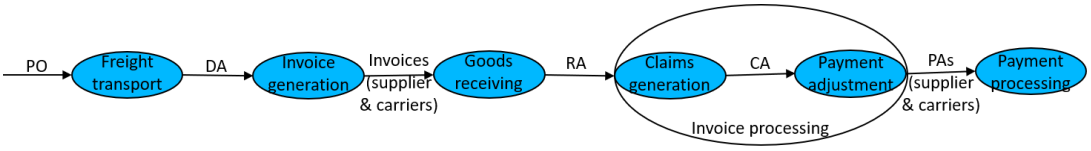

Fig. 1. Various processes in goods trade (domestic or global)

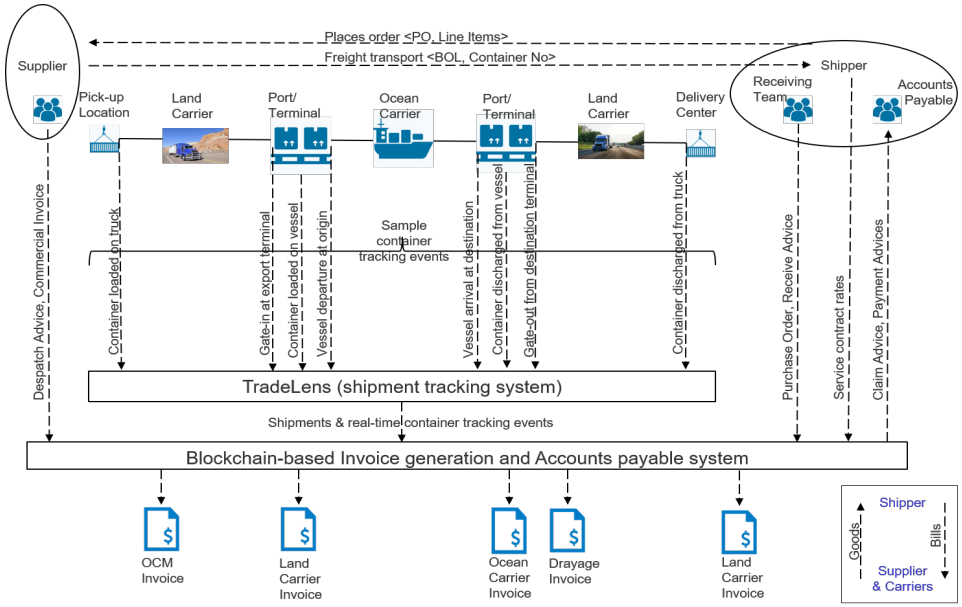

Fig. 2. Blockchain-based global trade transaction processing

Interchange (EDI) during goods trade. E.g., GS1 is one such EDI standard [4]. There exist one or more separate freight invoices and one supplier invoice (i.e., CI) in the case of a global trade transaction. In contrast, supplier invoice typically includes freight charges as well in case of domestic trade.

Discrepancy during the execution of any of these goods trade processes (Fig. 1) leads to disputes between the participants involved. To address the trust and transparency issues among the competitive and mutually distrusting participants of the supply chain network, the goods trade industry is adopting innovative solutions of late. TradeLens [5] is a blockchain-based solution to provide visibility into the current status of *freight transport* with the help of real-time shipment tracking events originated from different supply chain participants. Generating the invoices for freight carriers (e.g., Ocean Carriers or Drayage) involved in the goods movement from origin to the destination was carried out in [6], using the container tracking events and the shipment details captured by TradeLens as depicted in Fig. 2. In this paper, we propose a blockchain-based accounts payable system with capabilities to fulfill the needs of the supply chain network participants related to *invoice processing* (generation of CA and PAs). Our system also allows the shipper, supplier, and carriers to raise disputes on the generated *CA* and *PAs* and reconcile before *payment processing* with audit trails.

II. Related Work

While TradeLens [5] solution provides visibility into *freight transport* underpinned by blockchain, producing blockchain-based e-invoices for the freight carriers as part of the *invoice generation* process was addressed in [6], [7]. Several blockchain-based solutions exist related to financing during *payment processing* [8]–[11]. Use of blockchain technology for accounts payable (receivable) was discussed in [12]–[14]. Similarly, the possibility of carrying out matching of EDI documents on blockchain during *invoice processing* was discussed [15]. However, all these proposals typically initiate *invoice processing* after the goods delivery to the shipper. The blockchain-based *invoice processing* system in our paper breaks down the *claims generation* into claims under different categories where claims under certain categories can be generated and issued before the goods delivery to the shipper. The advantages of this approach are two-fold: *invoice processing* gets accelerated since the dispute process can take place before the goods delivery to the shipper, and dispute reconciliation becomes easier since disputes are handled at the granularity of claims under a category resulting in faster dispute resolution.

III. Implementation Details

The implementation details of invoice processing in our blockchain-based accounts payable system are presented in

this section. Here is the notation that we use. *PO.Q:* Purchase order goods quantity. *PO.P:* Price for each goods item as per purchase order. *DA.Q:* Quantity despatched by the supplier/quantity received by the shipper. *RA.Q:* Quantity accepted by the shipper after the verification by shipper's goods receiving team. *CI.Q:* Invoiced goods quantity by the supplier. *CI.P:* Price of a goods item as per supplier invoice.

A. Claim Advice generation

A smart contract is used to generate the CA for each PO on behalf of the shipper's *accounts payable* team as goods delivery progresses by analyzing EDI documents like PO, DA, RA, and supplier invoice (i.e., CI in case of global trade). Claims generated on behalf of the accounts payable team compensate for any damages to the received goods along with discrepancies in terms of goods received quantity or price against the PO. The accounts payable team typically computes the claim amount by exercising a 2-way, a 3-way, or a 4-way matching [16]–[18] of the EDI documents. In a 2-way matching, the invoice is matched to the purchase order to validate the *two* criteria that $CI.Q \leq PO.Q$ and $CI.P \leq PO.P$. In a 3-way matching, the invoice is matched to the goods received to validate a *third* criteria that $CI.Q \leq DA.Q$. In a 4-way matching, the invoice is matched to the goods accepted to validate a *fourth* criteria that $CI.Q \leq RA.Q$.

Matching EDI documents ensures that the shipper doesn't pay for goods that is not received or overpay for goods received. The shipper is entitled to pay to the supplier for the quantity of the accepted goods at the agreed price as per the purchase order, which is the amount $RA.Q * PO.P$. However, the payable amount as per the invoice by the shipper to the supplier is $CI.Q * CI.P$. The difference between the amount payable and the amount entitled to be paid is called as the claim amount to the shipper, which is equal to the amount $(CI.Q * CI.P) - (RA.Q * PO.P)$.

There can be price mismatch, or quantity mismatch, or both during the process of matching the EDI documents. We split the claims added by our blockchain-based accounts payable system to the CA document into *four* different claim categories.

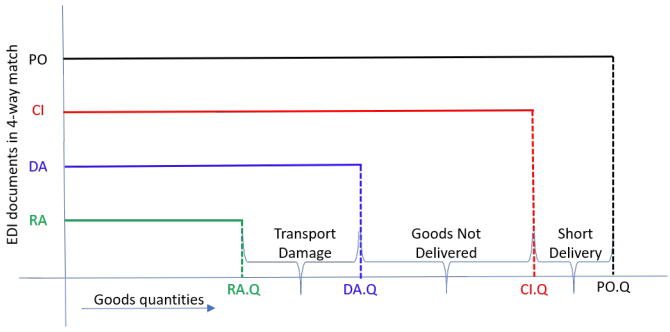

Fig. 3. Goods quantity discrepancies in a 4-way match when CI.Q $\leq$ PO.Q

1) Claim categories under the scenario $CI.Q \leq PO.Q$: Fig. 3 depicts the possible goods quantity mismatch discrepancies during a *4-way* match of the EDI documents PO, DA, RA, and CI under the scenario where $CI.Q \leq PO.Q$. The claims added to the CA document can be split into the following claim categories to represent the goods quantity mismatch, or price mismatch, or both.

- *SHORT_DELIVERY:* Difference in the quantity of goods between ordered (PO.Q) and invoiced (CI.Q) is captured as discrepancy under this category. $CI.Q \leq PO.Q$ implies partial fulfillment, which means that the supplier has not despatched all the goods quantity requested. The claim amount under this category is *0*.
- *PRICE_DISCREPANCY:* Difference in the goods price between supplier invoiced (CI.P) and ordered by the shipper (PO.P) is captured as a discrepancy under this category. $(CI.P - PO.P)$ attributes to the price change from what is agreed. The claim amount under this category is $(CI.P - PO.P) * CI.Q$.
- *GOODS_NOT_DELIVERED:* Difference in the quantity of the goods between supplier invoiced (CI.Q) and received by the shipper (DA.Q) is captured as discrepancy under this category. $CI.Q - DA.Q$ attributes to billed quantity mismatch. The claim amount under this category is $(CI.Q - DA.Q) * PO.P$.
- *TRANSPORT_DAMAGE:* Difference in the quantity of the goods between despatched by the supplier (DA.Q) and received by the shipper (RA.Q) is captured as discrepancy under this category. $DA.Q > RA.Q$ attributes to the shipper's goods receiving team not accepting the difference in the quantity $DA.Q - RA.Q$ as damaged goods. The claim amount under this category is $(DA.Q - RA.Q) * PO.P$.

The claim amount of a CA is the sum of the claim amounts under each claim category above. Thus the total claim amount of the CA is $0 + (CI.P - PO.P) * CI.Q + (CI.Q - DA.Q) * PO.P + (DA.Q - RA.Q) * PO.P$ which is equal to $(CI.Q * CI.P) - (RA.Q * PO.P)$.

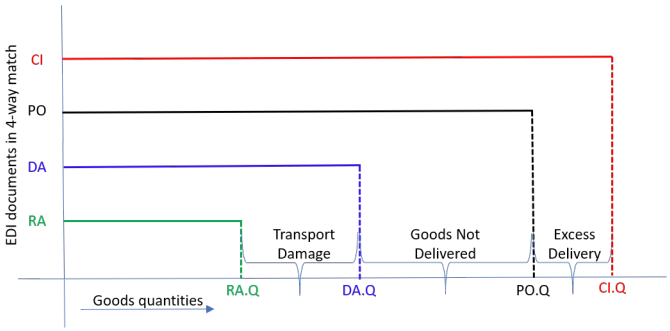

Fig. 4. Goods quantity discrepancies in a 4-way match when $CI.Q > PO.Q$

2) Claim categories under the scenario $CI.Q > PO.Q$: Fig. 4 depicts the possible goods quantity mismatch discrepancies during a *4-way* match of the EDI documents PO, DA, RA, and CI under the scenario where $CI.Q > PO.Q$. The claims added to the CA document can be split into the following claim categories to represent the goods quantity mismatch, or price mismatch, or both.

- *EXCESS_DELIVERY:* Difference in quantity of goods between ordered (PO.Q) and invoiced (CI.Q) is captured as discrepancy under this category. $CI.Q > PO.Q$ implies that the supplier has despatched excess quantity than requested. Claim amount in this category is $(CI.Q - PO.Q) * PO.P$.
- *PRICE_DISCREPANCY:* Difference in goods price between supplier invoiced (CI.P) and ordered by the shipper (PO.P) is captured as a discrepancy under this category. $(CI.P - PO.P)$ attributes to the price change from what is agreed. Claim amount in this category is $(CI.P - PO.P) * CI.Q$.
- *GOODS_NOT_DELIVERED:* Difference in the quantity of goods between supplier despatched (DA.Q) and ordered by the shipper (PO.Q) is captured as discrepancy under this category. $PO.Q - DA.Q$ attributes to billed quantity mismatch. Claim amount in this category is $(PO.Q - DA.Q) * PO.P$.
- *TRANSPORT_DAMAGE:* Difference in the quantity of the goods between despatched by the supplier (DA.Q) and received by the shipper (RA.Q) is captured as discrepancy under this category. $DA.Q > RA.Q$ attributes to the shipper's goods receiving team not accepting the difference in the quantity $DA.Q - RA.Q$ as damaged goods. The claim amount under this category is $(DA.Q - RA.Q) * PO.P$.

The claim amount of a CA is the sum of the claim amounts under each claim category above. Thus the total claim amount of the CA is $(CI.Q - PO.Q) * PO.P + (CI.P - PO.P) * CI.Q + (PO.Q - DA.Q) * PO.P + (DA.Q - RA.Q) * PO.P$ which is equal to $(CI.Q * CI.P) - (RA.Q * PO.P)$.

Note that $RA.Q \leq DA.Q$ holds good under both the above scenarios $CI.Q \leq PO.Q$ and $CI.Q > PO.Q$ as depicted in Fig. 3 and Fig. 4 respectively. And the total claim amount computed during the CA document generation under any scenario is the same and is equal to the amount $(CI.Q * CI.P) - (RA.Q * PO.P)$.

Moreover, by referring to Section I, the EDI documents PO, DA, and CI become ready for access on the supply chain network before the completion of the goods delivery to the shipper. And the EDI document RA becomes ready for access only after the completion of the goods delivery to the shipper.

Hence our blockchain-based accounts payable system generates the CA in two passes:

- *Pass-1 using only 3 EDI documents PO, DA & CI:* Generate claims under the $PRICE\_DISCREPANCY$ and $GOODS\_NOT\_DELIVERED$ categories along with the category $SHORT\_DELIVERY$ (if $CI.Q \leq PO.Q$) or $EXCESS\_DELIVERY$ (if $CI.Q > PO.Q$) as applicable before the goods delivery to the shipper on the occurrence of event like *container loaded on truck* from TradeLens shipment tracking system (refer to figure Fig. 2).
- *Pass-2 using all 4 EDI documents PO, DA, CI & RA:* Updates the CA generated in Pass-1 to add claims generated under the categories $TRANSPORT\_DAMAGE$ after the completion of goods delivery to the shipper post the occurrence of event like *container discharged from truck* from TradeLens shipment tracking system (figure Fig. 2).

This approach of breaking the CA generation into two passes in our blockchain-based accounts payable platform has an advantage with respect to letting the users (i.e., suppliers and carriers) access the CA much earlier than when the traditional accounts payable platforms would allow (i.e., where the users can access CA only after goods delivery to the shipper). Our system models the issuance of a CA and subsequent possible dispute (raised by supplier or carriers) workflows at the granularity of claims under each category.

3) Additional details on Claim Amount in CA: We assume that the claim amount can be negative without loss of generality, and a negative claim amount indicates the scenarios where the invoice is billed for fewer goods quantity than accepted by the shipper or billed at fewer goods price than agreed as per the purchase order among other possibilities. Additionally, whenever $DA.Q > PO.Q$, then we set $DA.Q = PO.Q$ as a preprocessing step. This ensures that the shipper never pays for goods quantity over the requested quantity $PO.Q$. We assume that there are no missing goods during *freight transport* and the shipper accepts $0 \leq RA.Q \leq DA.Q$ from the entire goods despatched by the supplier.

B. Payment Advice generation

A smart contract is used to generate a PA for each supplier and carrier associated with a PO. PA for any freight carrier typically reflects the carrier invoice amount. PA for the supplier is generated by deducting the claim amount captured in CA (excluding the claim amount under the TRANSPORT_DAMAGE category) from the supplier invoice. The claim amount for damaged goods is deducted from either the PA of the supplier or the PA of the OCM (which is also considered as a carrier), based on whoever had done the goods packing into the container (this information is captured by the TradeLens shipment tracking system).

IV. Evaluation

We simulate the system proposed in this paper using the Hyperledger Fabric blockchain platform. We showcased the performance of smart contracts for the generation of CA and PA using a representative goods trade ecosystem. The evaluation results convey that its practical to deploy one such system in real-world customer environments. We also observe from the results that the proposed system can easily support > 10 times the *invoice processing* load of the current global shipping industry [19]. Please refer to the full version of this paper [20] for more details.

V. Conclusion

In this paper, we provided details of our blockchain-based accounts payable system supporting trusted invoice processing and transparent dispute resolution. The claims against a PO are generated under four different categories and aggregated to produce the CA. The payment advices for supplier and carriers are generated by using the invoices for supplier and carriers respectively together with the CA generated by our accounts payable system and shipment details from TradeLens. The computed CA and PAs go through the reconciliation process before the payment gets processed by the shipper.

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