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Using Blockchain to Enhance the Trustworthiness of Business Processes: A Goal-Oriented Approach

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***Abstract*—Using Blockchain seems a promising approach for Business Process Reengineering (BPR) to alleviate trust issues among stakeholders, by providing decentralization, transparency, traceability, and immutability of information along with its business logic. However, little work seems to be available on utilizing Blockchain for supporting BPR in a systematic and rational way, potentially leading to disappointments and even doubts on the utility of Blockchain. In this paper, as ongoing research, we outline *Fides* - a framework for exploiting Blockchain towards enhancing the trustworthiness for BPR. Fides supports diagnosing trust issues with AS-IS business processes, exploring TO-BE business process alternatives using Blockchain, and selecting among the alternatives. A business process of a retail chain for a food supply chain is used throughout the paper to illustrate Fides concepts.**

***Index Terms*—Blockchain; Business Process Reengineering; Goal-Oriented Approach;**

I. Introduction

Business process reengineering (BPR) aims to redesign a business process, a set of ordered activities towards satisfying business requirements and delivering value to customers [1]. One of the challenges in BPR is how to renovate and innovate a current business process (the AS-IS process) to achieve requirements having trust issues among stakeholders (e.g., [2], [3]). A potential benefit of Blockchain, a framework for providing decentralization, transparency, traceability, and immutability of ledger and business logic, is known to enhance the trustworthiness among untrusted stakeholders [4]–[6]. Blockchain is expected to revolutionize numerous areas, and BPR seems no exception to this, but benefits from the use of Blockchain technologies to develop a better business process (a TO-BE process) - better in the sense of achieving the challenging business requirements unsatisfied by trust issues.

However, how do we utilize Blockchain for supporting BPR systematically and rationally with more explicit and formal representation? A few works seem to examine specifically this question, and this can lead the adoption of Blockchain resulting in a new business process that is supposed to help but hurt its intended goals.

In this paper, we outline Fides[1], both in the short-term and long-term, as the first study in its kind, to the best of our knowledge, and ongoing work. Fides is a framework for exploiting Blockchain towards enhancing the trustworthiness for renovative and innovative BPR, by helping in diagnosing AS-IS business processes having trust issues among stakeholders, exploring TO-BE business process alternatives that utilize Blockchain, and selecting among the options in a manner of systematic and rational, with explicit and formal representation. Throughout the paper, a business process of a food retail chain, where trustworthiness among stakeholders has been recognized as an important, and yet challenging concern, is used as a running example to illustrate Fides concepts.

This paper adopts key ideas from business process reengineering methodologies and business process management (BPM) technologies [1], and, in a complementary manner, extends them with a goal-oriented approach (e.g., KAOS [7], i^* [8], the NFR Framework [9], [10]), using Blockchain for alleviating trust issues among multiple stakeholders on business processes. Studies on using goals for systematic and rational BPR in general [11]–[13] are similar to our approach. However, our study concretely addresses trust issues among stakeholders on business processes. Moreover, we additionally construct a rational and systematic process utilizing Blockchain for enhancing the trustworthiness. More recently, some works have begun to appear on utilizing Blockchain for business process management [14]–[18]; In spirit, our approach is similar to them regarding adopting Blockchain to business processes, but our study goes beyond by considering business processes redesign, problems, and goals, and elaborating how to rationally and systematically integrate them all, using a goal-oriented approach.

Fides framework is introduced in Section 2. Section 3 summarizes this study and identifies topics for future work.

II. Fides: A Framework for BPR using Blockchain

Fides is to help in exploiting Blockchain systematically and rationally to enhance the trustworthiness of revolutionary and evolutionary BPR. Fides provides a process, described in Fig. 1, for diagnosing problems, discovering solutions, and redesigning business processes, and important concepts that Fides uses. Business processes (BP), problems (P), goals (G), agents (A), incentive (IC), smart contract (SC), data (D), and cryptocurrency (CC) are used as important concepts

[1]Fides is the Roman version of PISTIS in Greek mythology, the goddess of public trust

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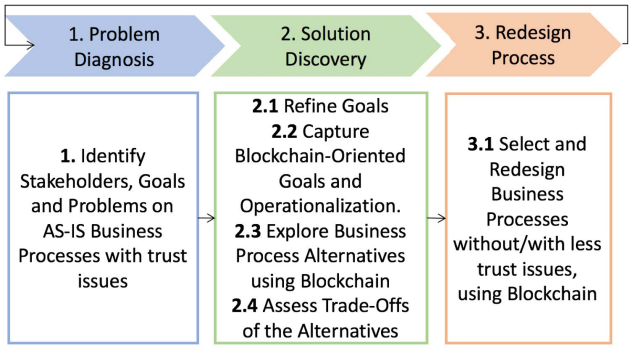

Figure 1. The Fides Process for Food Supply Chain using Blockchain

in Fides. The concepts and its instances are expressed as $(instance)_{concept_{label}}$ [20]. For example, enhancing the trustworthiness of food is an instance of goal (G) and labeled as 3 in Fig. 2. It can be represented as *(enhance the trustworthiness of food)*$_{G_3}$. In the rest of the paper, a food supply chain will be used to illustrate the concepts and the process.

The Fides process illustrates how an AS-IS business process having trust issues with implicit objectives turn into a TO-BE business process using Blockchain with an explicit goal model. The Fides process, which adopts key ideas of [1], [12], [13], consists of three stages; problem diagnosis, solution discovery, and a redesign process. The Fides process would be iterative, interleaving, and incremental with more information obtained at every step. However, in this paper, we sequentially describe each step of the Fides process for ease of illustration.

Fig. 2 illustrates an AS-IS business process and its problem diagnosis. In our running definition, a problem is a phenomenon that is against an agent's goal. Softgoal Interdependency Graph (SIG) extended with Problem Interdependency Graph (PIG) [9], [19] is used to capture stakeholders along with their goals and diagnose problems on AS-IS business processes in the way of explicit, formal, and systematic. In SIG, non-functional goals that have no clear-cut criteria of satisfaction-e.g., *(enhance trustworthiness of food)*$_{G_3}$-are expressed as softgoals, and operationalizations to *satisfice* softgoals-e.g., *(Use of a Food Certification)*$_{OP_1}$ are represented as an operationalizing softgoals. Each business task is labeled as T_i -e.g., *(select apples)*$_{T_1}$.

In *(an apples-selling process)*$_{BP}$ depicted in Fig. 2, *(to increase sales of apples)*$_{G_2}$, *a retailer*$_A$ *(wants to enhance the trustworthiness of apples)*$_{G_3}$ by *using (a food certification)*$_{OP_1}$. For *satisficing* OP_1 *and (reassuring retailers*$_A$ *about the quality of apples)*$_{G_4}$, *suppliers*$_A$ *are required to (request an inspection of their apples)*$_{T_{3,4}}$ *and (obtain a food certification)*$_{T_5}$ *from (an inspection organization)*$_A$. *Consumers*$_A$ *(use a food certification)*$_{OP_1}$ *(to assure the safety of apples)*$_{G_1}$.

However, *(when selecting apples)*$_{T_{1,2}}$, consumers$_A$ *(have a lack of trustworthiness of food certifications and inspections)*$_{P_1}$. Besides, consumers$_A$ *(have a lack of traceability and transparency on provenance information)*$_{P_2}$-e.g.,

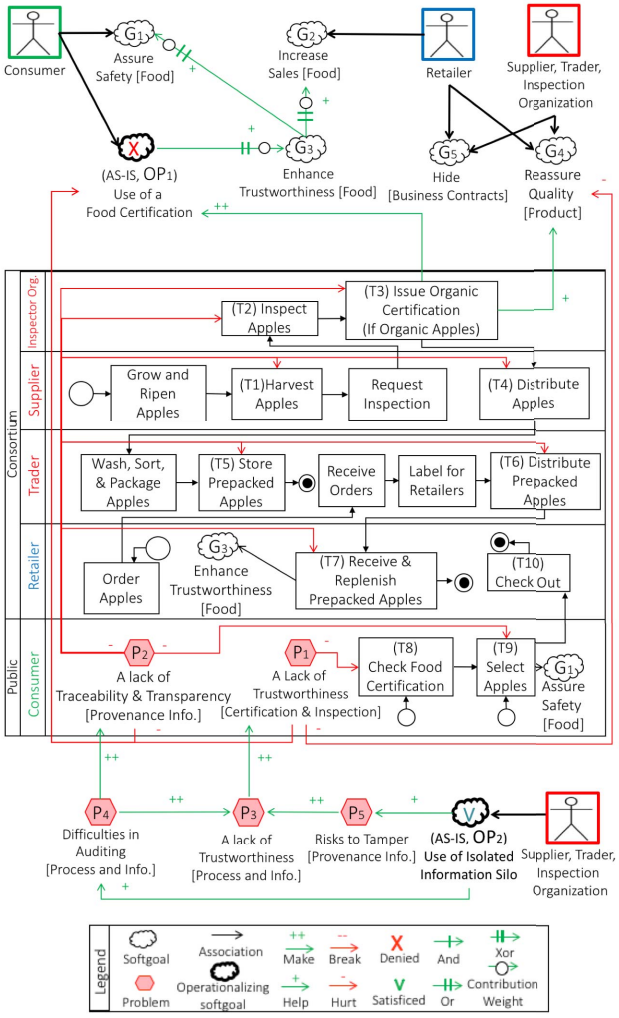

Figure 2. Problem Diagnosis on an AS-IS Business Process

(information of how the apples are produced, stored, and distributed)$_{T_{6-9}}$. The two problems show that use of a food certification is insufficient to enhance the trustworthiness of food. That is, *satisficing* P_1 *and satisficing* P_2 *hurt satisficing* OP_1, which means *weakly deniable*(OP_1) [9]. The cause of the problems results from *(use of isolated information silo)*$_{OP_2}$ of (suppliers, traders, and inspection organizations)$_A$. Since each stakeholder has ownership and control on their database, it is not only *(difficult to audit the information and their process)*$_{P_4}$ but also *(hard to prevent each stakeholder from tampering data to avoid detecting scandals)*$_{P_5}$. P_4 and P_5 *make (a lack of trustworthiness of their process and information)*$_{P_3}$; accordingly, P_3 *makes* P_1, and P_4 *makes* P_2. *Weakly denied* OP_1 turns G_3 into *weakly deniable*. As G_3 is *weakly denied*, G_1 and G_2 are propagated into *weakly deniable*.

To discover solutions, we refine the goal model, illustrated in Fig. 2 by capturing fine-grained domain goals along with

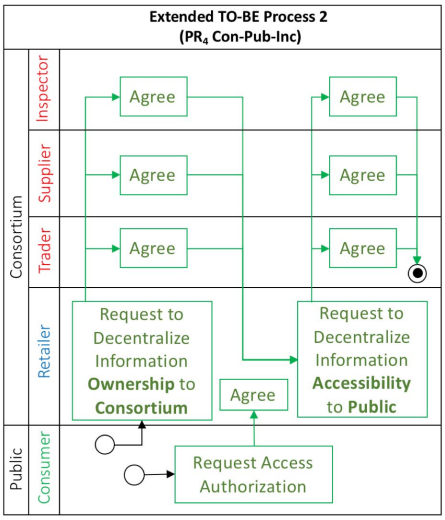

Figure 3. A extended TO-BE business process for having an agreement to the degree of decentralization on a Blockchain ledger

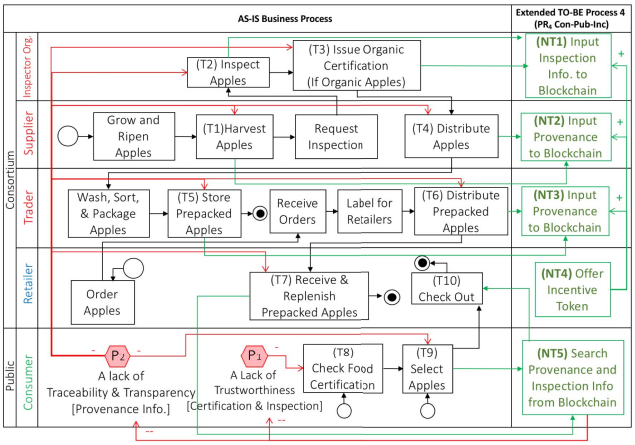

Figure 4. Redesign the AS-IS business process by using Blockchain after the decentralization agreement

Blockchain-specific goals and operationalizations. Since (the use a food certification)$_{OP_1}$ is turned out less satisfiable to achieve G_3, *(increasing the trustworthiness of food provenance information)*$_{G_6}$ is captured for achieving G_3. G_6 can be achieved by *(enhancing traceability of food provenance information)*$_{G_7}$ and *(enhancing transparency of food provenance information)*$_{G_8}$ [21], [22].

Our running definition of transparency$_{G_8}$ is the degree of *availability*$_{G_{17}}$, *accessibility*$_{G_{18}}$, *and immutability*$_{G_{19}}$ *of food provenance information (without loss, noise, or distortion)*$_{G_{19}}$ [21], [23]. Traceability$_{G_9}$ is defined as an ability to access any or all information related to food provenance information *accurately*$_{G_{10}}$ and trace upward and track downward at any time *quickly*$_{G_{11}}$ *(without the expensive cost)*$_{G_9}$ [22]. Fast$_{G_{11}}$ traceability can be satisficed by enhanced availability$_{G_{12}}$ and accessibility$_{G_{13}}$, *(transaction processing speed)*$_{G_{22}}$ and *(collaboration among stakeholders)*$_{G_{16}}$. Accurate$_{G_{15}}$ traceability is satisfiable by enhancing immutability$_{G_{14}}$ and the collaboration among stakeholders$_{G_{16}}$. The collaboration$_{G_{16}}$ among stakeholders is defined as a critical factor to deliver accurate$_{G_{10}}$ provenance information timely$_{G_{11}}$ since the quality of information depends on collaborative behaviors and attitude of suppliers and traders [24], [25].

However, (increasing transparency of provenance information)$_{G_8}$ is hurting *(hiding business contracts)*$_{G_5}$, while satisficing (increasing the trustworthiness of food provenance information)$_{G_6}$ [23]. G_8 helps to enhance the trustworthiness of the products for consumers, but there may or may not be unintended leaking of business contract information to other competitors. In case conflicting among goals while refining, it is necessary to prioritize stakeholders and goals and to qualify or quantify the goals.

Blockchain is a underlying technology helping in *(decentralizing ownership*$_{G_{18}}$ *and accessibility*$_{G_{19}}$ *of information and business logic)*$_{G_{18,19}}$. The information-e.g. food provenance information- and business logic are stored on a Blockchain ledger. The decentralization of a Blockchain ledger (makes availability$_{G_{17}}$ and accessibility$_{G_{18}}$ of food provenance information)$_{G_{17,18}}$. There is *(none of the updating or deleting functionality)*$_{G_{27}}$ on Blockchain, thereby data stored on Blockchain is immutable$_{G_{14}}$. In case of public Blockchain, users need to download a large volume of a Blockchain ledger, and the ledger size is rapidly increasing. Therefore, (the inexpensive traceability)$_{G_9}$ is defined as *(reducing the cost to store information)*$_{G_{15}}$ *(by preventing users from downloading ledger)*$_{G_{20}}$.

Blockchain has two options for decentralizing ownership of a Blockchain ledger-a public ownership of a ledger and a consortium ownership of a ledger. For example, *(anyone can download a public ledger)*$_{G_{23}}$, but *(only authorized entities, such as members of a consortium, can store a private ledger)*$_{G_{24}}$. Likewise, *the access level to Blockchain ledger is configurable to either the public*$_{G_{25}}$ *or consortium*$_{G_{26}}$. There can be three types of decentralization options, which are public ownership with public access, consortium ownership with consortium access, and consortium ownership with public access. Some Blockchain platforms, including private Blockchains, provide *(cryptocurrency functionality)*$_{G_{21}}$ as crypto-asset. Cryptocurrency can act as *(an immediate incentive)*$_{G_{17}}$ [5]. For instance, suppliers$_A$ automatically receive *Ether*$_{CC}$ as an incentive right after inputting provenance information *via a smart contract*$_{SC}$.

Therefore, we can derive five kinds of TO-BE business process alternatives using Blockchain. PR_1 (Pub-Pub-Inc), using a public Blockchain, allows the public to download and access to a public ledger with the use of cryptocurrency. PR_2 (Con-Pub-), using a private Blockchain without cryptocurrency, provides consortium ownership of a private ledger, but public users are allowed to access the private ledger by authentication. PR_3 (Con-Con-) is only for the consortium to store and access a private ledger without cryptocurrency

functionality. The three TO-BE business processes, PR_{1-3} are to have an agreement with retailers, traders, and suppliers, and inspectors about the decentralization degree of ownership and accessibility. PR_4 (Con-Pub-Inc) and PR_5 (Con-Con-Inc) are same as PR_2 and PR_3 respectively but use cryptocurrency.

Because PR_1 uses a public Blockchain, PR_1 (Pub-Pub-Inc) breaks G_{20}, G_{22}, G_{24}, and G_{26} and makes G_{21}, G_{23}, and G_{25}. By utilizing a private Blockchain, PR_{2-5} help G_{22}, break PR_{23}, make G_{24}. A private Blockchain only allows consortium, which means $PR_{3,5}$ make G_{26} and break G_{25}. However, because $PR_{2,4}$ allow the public to access a private ledger by authentication, $PR_{2,4}$ help $_{G25}$ and hurt G_{26}. By utilizing Blockchain, $PR_{1,5}$ make G_{27}.

To evaluate TO-BE business process alternatives, goals act as evaluation criteria. We utilize SIG goal evaluation scheme [9] to qualify satisfactions of goals described above. $G_{6,7,8}$ are prioritized to determine a TO-BE business process that more satisfices the goals than other business process alternatives. Because G_8 and G_5 are conflicting, G_5 is also prioritized to qualify for goal dissatisfaction. A TO-BE business process that more satisfices $G_{6,7,8}$ and less dissatisfy G_5 needs to be selected.

PR_4 is selected according to the goal evaluation scheme [9] and used for BPR, illustrated in Fig. 3 and Fig. 4, to enhance the trustworthiness of the business process. Fig. 3 describes an extended business process for having an agreement to the degree of decentralization on a Blockchain ledger according to the PR_4. In the agreement process, a retailer configures the ownership and accessibility of a Blockchain and initiates the agreement process. After traders, suppliers, and inspectors agree, the retailer creates a Blockchain network according to their new business process. Fig. 4 depicts the TO-BE business process, PR_4, using Blockchain. Traders, suppliers, and inspectors input the provenance and inspection information to the Blockchain, and a retailer provides incentive using cryptocurrency to them. Consumers can access the provenance information from the Blockchain after getting authentication from the retailer. Green-colored business tasks are new business tasks using Blockchain and the new tasks alleviate P_5 that hurts $T_{1-7,9-10}$. Since consumers are not relying on the certification and inspection, P_1 is alleviated.

III. Conclusion

In this paper, as an ongoing work, we outline Fides, a framework for utilizing Blockchain towards enhancing the trustworthiness of business processes. A main technical contribution in Fides is a systematic and rational process, with a more explicit and formal representation. Another byproduct contribution is a preliminary reference process model, for using goals for diagnosing problems on AS-IS business process with respect to trust issues among stakeholders, exploring TO-BE business process alternatives that exploit Blockchain, and selecting one among the alternatives.

There are several lines of future work. We are currently developing an ontology for Fides and a comprehensive meta-model for the food supply chain and beyond. We are also working on a tool for facilitating the use of Fides. We also plan to experiment our approach with a university and a company, as well as a variety of other types of applications.

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