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ABSTRACT

Visibility in a supply chain brings benefits across all partners, leading to positive effect on overall supply chain performance. IoT-based approach has been shown to be effective in enhancing end-to-end visibility. An IT artifact can be designed to deliver supply chain visibility to individual users. Yet, factors like ownership, costs, and know-how often deter the adoption by supply chains. In this paper, we present the design of a cloud-based IT artifact for supply chain visibility services. With IT services and a service-oriented approach to visibility, a concept of visibility cloud (VC) is proposed. The design objectives of VC are articulated, leading to two key services formulated as Visibility-as-a-Service and App-as-a-Service. The two services are described and followed by an illustrative instantiation. VC servicetizes SCV with affordability and expandability according to the pace of each individual party. With metered SCV services via mobile devices, supply chain management is effective definite (definite effective?) anytime anywhere.

Keywords: Supply chain visibility, IoT, Service, IT Service, Visibility Cloud

INTRODUCTION

Supply Chain Visibility (SCV) has been taunted as a game changer that will bring supply chain performance to the next level. Yet, the pursuit of visibility remains challenging with no tangible artifacts. Emerging technology though offers on-demand facilitation and data-rich embedded component to support the innovative design of SCV as do-it-yourself (DIY) pay-as-you-go (PAYG) IT services. The conceptual development of SCV with a cloud-based operationalization scheme is proposed in this study.

For obvious reasons, current status of any operations of a supply chain party is visible to the human eyes, at least within four walls. Such analog visibility, such as CCTV, does not precisely describe the situation, and the view requires interpretation with trained eyes. Digital visibility is possible given the right data is persistent in store and shared. Visibility involves two defining parties – the one who *sees* (or the *see*) and who *be seen* (or the *seen*). Value proposition from each often cannot take what the other party needs or has respectively into consideration. Only at service exchange, such proposition could be aligned, giving an effective SCV delivery – the *seen* has a continuously improving rich data pool with respect to business processes, and the *see* has a visibility requirement at the time of need articulated based on data availability.

Internet of Things (IoT), Internet connected objects embedded with sensors and/or actuators, adds identification and real-time data dimensions within supply chains. With IoT technology, the right corporate transactional data can be coupled with dynamic and real-time operational data that are attached to known entities. This added data dimension could be simply the on/off of the sewing machine in a production factory – a more precise level of detail, or that particular WIP item that just passed through the outbound exit door onwards to the warehouse across border – a wider net of data coverage. The identity of an entity as IoT data serves as an integrative glue to scattered corporate data. Benefits of RFID have been suggested and the technology has been implemented in supply chain and logistics management, and in other industries such as retails and healthcare.

IT as a service has revolutionized corporate IT strategy from ownership to PAYG services, from infrastructure (IaaS) to software (SaaS). Common definable procedural processes are well positioned to deploy as SaaS, executed in third-party owned IT resources & based on a pay-per-use cost model. Despite some data privacy and security concerns, metered IT services also offer fault-tolerant and optimization, especially critical to global e-merchants and social media sites where activity spikes are common and any downtime is unacceptable to the users.

In this paper, Design Science Research (DSR) approach is followed to offer a design of a cloud-based service-oriented artifact for SCV. Contributions takes in the form of a paradigm shift approach to SCV, which is not designed as a software component to buy and install, but is as a service that provides clarity and fidelity in supply chain management. SCV is enabled by the provision of an IT artifact in the cloud that delivers effective on-target and on-demand SCV for supply chains via services as mobile apps – the design artifact is termed Visibility Cloud (VC).

In the following section, literature on a number of keys concepts behind the service-oriented VC is discussed. Based on the interplay of these concepts, and a Visibility Platform (VP) artifact, a foundational premise is established. Description of our design attempt to formulate two new services of the VC, followed with an illustrative instantiation of a typical supply chain scenario via mobile apps. Concluding remarks on this work-in-progress research on mobile visibility service are given at the last section.

LITERATURE REVIEW

Adoption of RFID technology in supply chain management has been discussed [27, 5, 11, 12], with benefits shown to reduce shrinkage and create overall cost savings [24]. The IoT role in visibility of supply chains is also discussed with possible accuracy in stock level, and allows proactive reaction to information from upstreams or to downstreams (e.g., consumption point) [6]. Time-temperature monitoring in perishables moving from ambient chain to cool chain has been argued to reduce spoilage and maintain product availability [14].

Supply chain visibility brings obvious benefits based on articulated information sharing and availability [2]. The lack of supply chain visibility has been a top concern [7] and to gain a basic level of visibility one relies on packaged software such as Excel and in-house applications [8]. SCV involves the undeclared cooperation of two parties: the one that receives the visibility view for making a wise decision (the '*see*'), and the ones that 'create' the data (the '*seen*') as information flow in the supply chain. The former is referred to a Wiser, and the latter as Maker in this paper – a duality of visibility that is crucial in any SCV design.

Based on different perspectives of supply chain visibility in the literature [22, 23], a number of characteristics are suggested – contextual in nature, and right information sharing such as product tracking. A definition of SCV for discussion is given: SCV is *the availability of supply chain actionable status*. Two dimensions of SCV are also declared: clarity and fidelity based on the general meaning of 'visibility' as how *clear* and how *far* one can see, and is also suggested as data quality dimensions [26]. SCV with clarity shows associated upstream and/or downstream information traces, while fidelity provides data comprehensiveness drilled down to the item level of supply chain entities. For the purpose of this paper, the *breadth* of information is used for clarity in following discussions, and *depth* for fidelity.

Currently, to the best of our knowledge, there does not exist a reference framework or models for guidance to bring visibility in supply chain management. An attempt is made to prescribe a framework, from the perspective of IoT, to gain visibility in a systemic way in an accompanying paper in this conference [16]. One example of an implementation of SCV facilitated in a Visibility Platform (VP) is described in [15], and a general view of the VP framework is based for a self-service extension.

There are a number of design science research approaches proposed in rigorousness and communication practice [9, 21]. In here, we follow the publication schema given in [10]. A thought process is described next before the artifact VC description is provided. Evaluation and discussion as concluding remarks will then follow.

Supply Chain Visibility: Services in a Cloud

Supply chain partners work together intellectually to contribute to overall performance as a whole. Interestingly enough, SCV should take on a service view accordingly to the inherent duality characteristics of visibility in general. Service-dominant logic is a view offered to overtake the traditional goods-dominant logic in marketing [25, 19]. Actors of the economy work together in a service setting to co-create value. In the context of SCV, the Wiser(s) and the Maker(s) work together independently to co-create value for the supply chain. SCV with clarity and fidelity brings improved performance overall and across individual partners. In the exchange of knowledge, each Maker knows specifically how data are to be generated and collected that are precise and crucial. Each Wiser knows how to make use of the available data to compose a visibility view with accuracy and currency that is effective in supporting a decision with high confidence level.

Such service in the physical world can be transformed into e-Service with collaborative efforts among all parties [4]. With a SCV envisioned by the Wiser, the delivery of the on-demand view can be a Party e-Service [3]. The concept of multiple parties participates in an e-Service that brings SCV to one or all involved is intrinsic. The clarity of a view is undoubtingly improved with collaborative efforts from participating parties. SCV for a warehouse manager on a SKU is much improved if during the composition of the view, the factory manager contributes his input on specific data availability, both corporate and IoT, and (one-time) permission for other in-depth information. The notion of collaborative e-Service positively influences clarity and fidelity of a SCV is warranted.

Technology with a service perspective continues to flourish such as service-oriented computing (SOC) [20] and cloud computing (CC) [1]. SOC studies the critical components that can be designed to enable services in an electronic web-based environment. With CC, metered IT services can now be obtained from software (SaaS) down to IT infrastructure (IaaS), allowing different service levels for delivery and performance of e-Services. Such development extends the service concept into IT services, e.g., IT computing environments are software-defined, or SDEs [17]. IT resources are configured on-demand with flexibility.

The notion of "services in a cloud" stems from a single concept: service. A broaden view of service innovation suggests frameworks of service ecosystems, service platforms and value co-creation [18]. Value co-creation is inherent in SCV. Mobile e-Service is the next frontier for SCV to reach [13].

SCV is a service-oriented exchange. The service is enabled in an electronic environment with a collaborative nature. The e-Service is deployed in the cloud environment. Service experience is via mobile devices. That is, SCV is a service exchange between collaborative supply chain parties in a cloud-based mobile environment. The design of an IT artifact is provided next to bring IoT-enabled SCV to the masses.

An IT Artifact: A RFID-Based Visibility Platform

A case scenario where a VP was implemented for an actual garment supply chain enabled in the design process with RFID technology is used as a starting point for SCV. Digital visibility is built with data, in which data is both generated and collected. Generation is often driven by business transactions. Targeted collection of data is enabled with IoT technology. A third element that would not be considered in this writing is data interpretation – social media data, part of a big data suite, are interpreted for SCV purpose with tools such as opinion mining and sentiment analysis. Social media data include mostly data sources that are not controlled by the respective supply chain.

Next, the IT artifact that forms a foundational premise for VC is briefly described. The RFID-enabled garment supply chain, referred to as ActiveWear, a fictitious name, in this paper with manufacture facilities located in South China and Hong Kong will be used.

Figure 1 depicts the design process of an artifact that enables visibility in a supply chain with the incorporation of IoT. IoT data is collected with pinpoint accuracy with respect to business processes driven by management actions. The VP is the IT artifact embedded into the operations of the supply chain, creating and integrating data and information for end-to-end visibility.

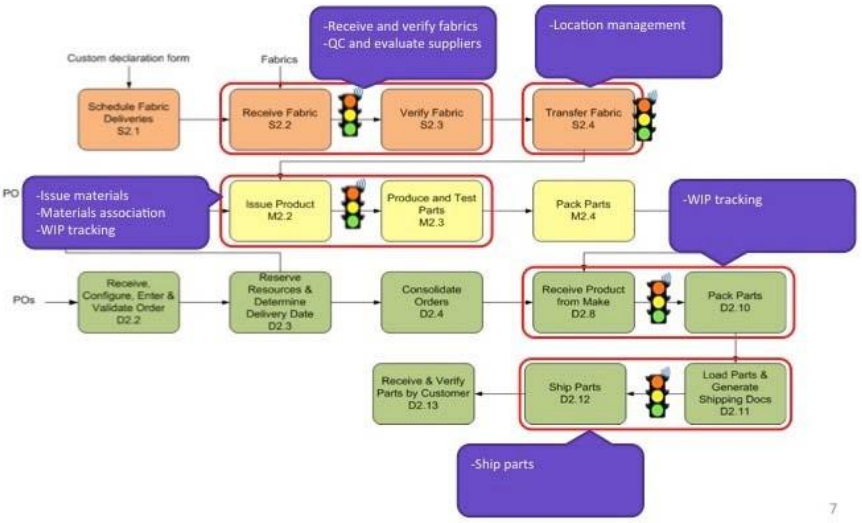

Figure 1. Enabling Visibility with RFID of a Garment Supply Chain

Given the design, a VP is built with acquired hardware and networking equipment distributed across all partners in the supply chain. The infrastructure and networking work requires expert domain knowledge and intensive testing as equipment specification standards and broadband communication service levels are different in Hong Kong and China.

The process begins with a charting of all supply chain business processes using the standardized tool SCOR (such as the Source, Make, and Deliver process components). With this supply chain business process (SCBP) map in hand, pain points are identified based on articulated management's concerns and suggestions. RFID technology is then introduced at those points (shown as 'traffic lights') targeting directly the SCBP(s) to capture relevant data. With this new real-time data, a data pool coupled with corporate's transactional data, is made available in the VP for the facilitation of visibility views' creation. A reference framework is currently being developed for this process [16].

Operationalization of SCV is illustrated with the above case scenario. Next, a design approach is attempted to bring the service concept into supply chain visibility. That is, visibility services enabled in a cloud environment as apps deployed from the 'app vault.'

DESIGN ARTIFACT – VISIBILITY CLOUD

Visibility is a double-edged dilemma – two asynchronous parties take on requirement that could very well be conflicting and even have an unreachable goal. The 'seeing' cannot foretell what the needed visibility is, and the 'seen' cannot tell what data constitutes a visibility ahead of the demand.

A Visibility Cloud artifact is designed to provide a visibility creation service via a configured VP provisioned for the supply chain, and a visibility activation service via a managed vApp (visibility app) store. SCV is a service achieved by an on-demand provision of a Visibility Cloud, inherent much of the cloud computing benefits from an enterprise IT strategic position perspective.

The creation service is defined as a Visibility-as-a-Service (VaaS) where visibility services of supply chains are enabled. Each supply chain has their own VaaS layer, or supply chains can also share one. Above this layer is the activation service where mobile apps are served to devices as App-as-a-Service (AaaS). The management policy of this layer differs per VaaS, or per supply chain within the same VaaS. The design considerations of these two service layers are discussed after the design objectives of VC are stated next.

The requirement of 'anywhere anytime' is fundamental to any e-services, or cloud-based e-services. Offering a visibility view of a supply chain is a phenomenon we call *an instance phenomenon*. That is, the value of a visibility view can only be defined with respect to that particular time instance. The phenomenon is characterized by on-demand, currency and soft real-time. In a supply chain context, that phenomenon is governed by the identity of the user, where the user is at the time of invocation, and the time marker for the request. While the Maker ensures that the data pool is rich, each datum is sensitive with respect to the role of the Wiser, and whose relationship with other parties in the supply chain. Three design objectives are defined for the VC, namely, 1) Identity-aware, 2) Temporal-Sensitive, and 3) GoeSpatial-aware. These objectives are considered in the design of the two layers in VC structure.

Service Stacks in Visibility Cloud

Figure **2** illustrates the two new services in a cloud computing model for the VC. The infrastructure and platform environment are also known based on the runtime parameters, such as computing power, storage requirement and memory size support.

Figure 2. The Visibility Cloud (VC) Service Stack

A VP shell is packaged, e.g., a clean snapshot image, for activation on top of PaaS. Supply chain configuration specifications, e.g., business processes and hotspots, and others will be used to tailor the VP mechanism/software system for a particular supply chain. VaaS is a collection and creation facility. AaaS is the retrieval, activation, and delivery facility.

Visibility-as-a-service (VaaS)

VaaS facilitates participants in a supply chain to personally enable a visibility view by provisioning a VP with specific supply chain parameters. The composed SCV is immediately available for view and validated vApp deployment. The service will have these design considerations:

- A VP for provisioning with respect to a supply chain configuration
- A visibility view management for on-demand creation.
- A visibility data delivery mechanism to active vApps.

Supply chain configuration parameters include the following maps, 1) Business Processes Map, 2) Hotspot Activation Map, 3) IoT Data Schema and Flow Map, and 4) Relationship Map.

With the VP artifact in place in the VC, visibility views are defined as needed. Users of the VC, a community of supply chain staff, operational or managerial, begin their personalized visibility view construction, either as ad hoc or common visibility views to monitor and keep abreast of current statuses of supply chain. The identity of all users, along with their individual credentials and roles are properly incorporated into the VC. That is, a view when defined is associated with those who can use the service, with any location-specific restriction, and at the time of day when the service should be active.

This service alone enables visibility at points where a networked computing unit with a web browser exists and can be shared by many staff of the same unit. Our design extends to a mobile environment with access natively by networked smart devices.

App-as-a-service (AaaS)

Visibility views created at VaaS are instantiated as vApps and served on-demand from the Visibility Cloud functionally characterized by the user's role (identity-aware), time of need (temporal-sensitive), and the location of the user (geospatial-aware).

AaaS brings SCV to the mobile environment with personalization and location-based security. Mobile apps that are offered by commercial entities such as banks and e-retailers are prominently promoted on their websites and physical stores. The app is free to download into anyone's smart devices from two major 'stores' serving the iOS and Android mobile platforms. Personalization is often defined inherently with the smartphone's profile information (e.g., phone number, or email login account), not the physical person that is using it.

Similar approach on the management of apps is suggested for enterprises with vApps. Employees of the enterprise have the right to access the AppVault (use of AppStore is avoided) once approved. A given vApp can be downloaded into the smart device of the employee once the credentials are validated. The vApp will be enabled by location based information (such as a designated GPS range, or by reading a NFC-location identification tag at site, or both), or identity information (such as facial recognition or fingerprint).

Design considerations for AaaS are:

- vApp manifestation – given a visibility view created via the VaaS, a quick transformation must be effected to a standalone application (vApp) for common mobile platforms.
- vApp configurability – each vApp is properly wrapped for identity, temporal and spatial control.
- vApp management – vApps for a given supply chain continues to grow, and retires as needed. Each vApp is downloaded from an AppVault where vApps reside.

Apps-as-a-service can take up different operating models clearly viewed from a service perspective. At this writing, the services are scoped within the community of a supply chain. In some configuration, a brand owner enables all managerial staff with AaaS according to the echelon of the supply chain the staff's responsibility. Services could also be managed by a third-party entity similar to outsourcing the apps management.

DISCUSSION

Evaluation of the artifact with respect to the VP of ActiveWear has been carried out. The VP is deployed in a private cloud (OpenStack) for the Visibility Cloud of ActiveWear, using a snapshot of the VP created in storage. Via the cloud management console, the ActiveWear VP is provisioned as a VaaS based on the configuration maps that have been created for the supply chain. A ReplenishmentStatus vApp, in our case, is designed as an app (only the design has been done, not the actual implementation) for Android mobile devices based on a view created via the VP by a Wiser. Moreover, whe material design by Google is used to design the vApp. The design of a vApp requires further investigation regarding privacy and security concerns, for activation control, and survivability.

A Visibility Cloud, by default, is fault tolerant and resilient. Current discussion is purely on one supply chain and one VC. Such notion is not necessary conducive in a supply chain network where collaborative efforts can be extended across supply chains. A community of VC's of vertical supply chains can be designed with an integrative view of all business processes, effectively enabling data flow across supply chains with entitlement bridges.

Design principles of VC are manifested in VaaS with a basic policy specification, while the enforcement is carried out based on an entitlement specification at visibility delivery embedded within the vApp. Overrides could be designed to allow a one-time modification to the view for effective collaboration, but the policy change does not carry back with the vApp.

Based on the DSR Knowledge Contribution Framework, VC is an invention, as delivery of on-target on-demand SCV is a new problem. The solution is based on emerging technology development with a service view that SCV is a knowledge exchange of the Maker and the Wiser. The exchange is encapsulated in a descriptive view template, visualized in an App-as-a-Service deployment, and delivered on-demand as a service would and should, leveraging a powerful IT service paradigm, that the IT artifact Visibility Cloud is provisioned quickly with infrastructure and platform specifications.

CONCLUDING REMARKS

To remain competitive as a supply chain, its management practice, agile or lean or otherwise, must garner performance with achievable cost savings and wastage reduction. Supply chain visibility has been argued to be a valuable capability that could lead to better performance. Efforts in gaining such covert visibility often run into hurdles such as information sharing, data quality, IT investment, un-sustained ROI arguments, and the best visibility to have – the duality nature of visibility.

Visibility Cloud takes the concept of service into play, argues that purposeful data must be identified, created if they do not exist, shared when necessary, leverages big data such as IoT and social media, and such diverse on-target data pool enhances on-demand visibility, delivered by provisioning, and delivered to personal mobile devices. With VC, SCM is effective definite anywhere anytime.

This paper is a work-in-progress. Supply Chain Visibility can also be quantified as Supply Chain Analytics (SCA). That is, SCV is discussed as a view in this study, and it should not only be as such. Data gathered according to the visibility needs of a

user can be passed to an analytical engine to project further, e.g., with historical data and social trends and influences, a credible scenario of time in the near future. Models with prescriptive nature can also be used or developed accordingly.

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