Enabling Integrated Information Framework as Cloud Services for Chemical and Petroleum Industry

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Abstract—**Business agility is of vital importance to chemical and petroleum industry, especially in rapid response to diagnose and exchange of real-time information and other relevant data sources. From IT perspective, emerging delivery models such as cloud computing offer the possibility to build the elastic infrastructure and flexible computing platform, thus enable enterprises to focus on their core competences. In this paper we investigate how the new delivery models of cloud service achieve the improvement of the efficiency by means of Integrated Information Framework (IIF) of chemical and petroleum. In infrastructural level, the capabilities and implementation mechanism of cloud based IIF solution lifecycle management are presented. Based on such management foundation, a business process environment delivered in Platform-as-a-Service business model is provided for rapid development of business agility. Finally, IIF in public and enterprise SaaS models to enable the chemical and petroleum value chain and service market is discussed. This paper demonstrates how the cloud computing technologies and architecture patterns significantly enhance the capability and agility of not only chemical and petroleum using IIF, but also the enterprise with similar requirements, business models and IT architectures in other industries.**

Keywords- Cloud Computing, Elastic Intrastructure, Platform-as-a-Service, Software-as-a-Service, Chemical and Petroleum

I. INTRODUCTION

The chemical and petroleum (C&P) industry is now facing more and more challenges from its daily routines. The toughest one is information visibility and accessibility. The ability to make timely, smart business decisions about operations and production performance directly drives the overall effectiveness, efficiency, and production that come from a plant, a field, and the equipments and assets supporting them. Unfortunately, in most chemical and oil production operations, the information needed to make these vital business decisions is often too little or too late to be truly effective.

The challenges can be summarized as follows [1]:

- Time to market of business growth initiatives impacted by deployment capability of IT resources;
- High labor costs associated with manual IT resource deployment processes and procedures;
- Inability to respond to variations and spikes on demand;
- Business agility limited due to workloads being tied to IT resources;
- Inability to migrate workloads to more cost effective and efficient computing environments.

It has been predicted that competitive success will belong to organizations that are able to cope with rapid external and internal changes in the future trend. It is indicates that business agility is an organization's ability to sense environmental change and respond efficiently and effectively to that change [2]. The challenges faced by chemical and petroleum industry become the barrier to business agility. For example, oil and gas wells generate a torrent of technical and financial data throughout the exploration and production life cycle, while these information is significant important and invaluable to support decision–making.

Integrated Information Framework (IIF) for Chemical and Petroleum [3] is a software framework for exchange of real-time information and other relevant data sources across multiple systems. Meanwhile, IIF physically takes on a form with such a comprehensive middleware portfolio, that it needs an efficient as well as convenient delivery model in the business sense. It consists of business process server, business event engine, model server and database, and client side solution studio for a uniform view of aggregated data from distributed system. As a framework, it also provides a set of APIs in the form of Web Services, RESTful Service and Java API for development of process centric and event driven application to meet the requirements of various enterprises along the value chain of chemical and petroleum industry.

Today's economy tide is forcing chemical and petroleum enterprises to address the complex issues in pursuit of higher return on investment (ROI). They are beginning to investigate the benefits of the new information technologies. Cloud computing promotes a new dialogue between business and IT decision makers. Cloud computing focuses its strength on business service priorities to gain better IT resource utilization, reduced cost of operations, faster business service provisioning, and better alignment of IT spending to business service level requirements. On one hand, cloud computing is exemplified as an ultimately virtualized system and a natural evolution for data centers that employ automated systems management, workload balancing, and virtualization technologies [4]. On the other hand, cloud computing accommodates a new range of services and applications delivered to customers through a number of business models, most prominently Software-as-

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a-Service (SaaS) and Platform-as-a-Service (PaaS) models [5][6].

By leveraging both the IIF built-in competencies and cloud computing delivery models to maximize productivity and efficiency of chemical and petroleum industry, we designed and implemented the cloud enabled IIF solution, to address the above requirements and enable IIF with cloud computing in 3 layers:

Elastic Infrastructure – Cloud based IIF solution lifecycle management for rapid and easy customization, deployment and scaling of IIF as the base framework with specific solution topology, middleware, database and common applications, which significantly reduces the workload and shorten the time to build such solution in an enterprise cloud environment.

Business Process Centric PaaS – IIF business process environment for off-premise development and automatic deployment of process centric and event driven applications based on IIF APIs, especially for IIF KPI (Key Performance Indicator) process.

Programmable Enterprise SaaS – IIF in SaaS model to enable the new business model for value chain and market place of service for the chemical and petroleum in cloud environment, by leveraging the application development in PaaS model.

The reminder of this paper is organized as follows: Section 2 introduces the cloud based IIF solution lifecycle management for flexible deployment and scaling of the system for chemical and petroleum enterprises with different system scale. Section 3 presents the IIF business process environment in PaaS model for off-premise development and deployment of process centric application for IIF in cloud environment. Section 4 discusses the value proposition of cloud enabled IIF in SaaS model. Section 5 summarizes the observations, conclusion and forecast.

II. CLOUD BASED IIF SOLUTION LIFECYCLE MANAGEMENT

Cloud infrastructure construction plays a significant role in the maximization of business profits [7]. By leveraging virtualization technologies, Cloud based IIF solution lifecycle management, as the first layer of Cloud Enabled IIF solution, provides the elastic infrastructure for automatic deployment, vertical scaling (scaling-out and shrinking), horizontal scaling (scaling-up and scaling-down), and software upgrading, for the whole solution lifecycle with following phases:

Creation - Service offerings (III. A.) bearing industrial best practices are predefined as assets for rapid reuse. Specialized service offerings are also allowed to be customized by users according to the individual environment. For instance, besides the full solution topology, the partial topologies may be customized as a complement to the existing solution environment.

Deployment - The required deployment parameters including hardware resource configuration, operation system and application software level configurations are provided as input for the deployed service instance (III. B.). Service offering defined in preceding phase will be deployed automatically to create the service instances.

Management - The dynamic scaling and automatic software upgrading capabilities will be performed to the elastic infrastructure according to the real monitored performance. The highly scalable and reliable management is vital to successful and economical operation of computing resources in a cloud environment [8].

A. Creation

The service offering (SO), which depicts the solution topology and configuration, is defined in the creation phase and then will be instantiated in the deployment phase. One service offering may be instantiated as multiple service instances of different system topology.

We formulize the service offering as follows:

SO = <SN, DEP, ORD>, where

SN = < SCP, OSC, HRP>

The detailed explanations for the above formulation are:

- ***SN*** denotes the service node within the service offering. Generally, it represents the virtual machine in the cloud computing area.
- ***DEP*** indicates the dependency relationship and constraints among the service nodes, especially the software interaction configuration constraints. For example, the application server should identify the database server configuration information to make the database connection available.
- ***ORD*** specifies the special startup and shutdown constraints among the service nodes. This is critical to render the solution successful because the startup order of the service nodes can influence the application running status.
- ***SCP*** defines the specific software configuration parameters. For example, the cluster configuration parameters are used to describe the topology and the clustered members of application server and process server.
- ***OSC*** defines the operation system level configuration. For example, the network information can be defined for each deployed virtual machine to describe the IP address and hostname, etc.
- ***HRP*** defines the underlying hardware resource properties. For each deployed service instance, the hardware configuration should be specified, such as CPU number, memory size, and disk size, etc.

B. Deployment

In the deployment phase, the pre-built or custom service offering can be provisioned into the real physical environments. Naturally, the required hardware and other resources (e.g. IP address, etc) should be verified as available for the deployed environment.

There are 3 types of parameter values to be consumed by the deployment process. The first type is the user specified values, such as CPU number, memory size and some software configuration parameters. The second type is the system allocated values from the resource pool, such as IP

address, etc. End user can not manually specify this type of value in order to make the deployed environment controllable. The last type is for other dependent service nodes, which denotes the constraint and dependency.

The deployed service instance (SI) is the instantiation of the selected service offering with the values of the required parameters specified.

We also formulize the service instance as follows:

SI = <SO, USV, SAV, SCV>

The detailed explanations for above formulation are: ***USV*** specifies the user specified values of the parameters; ***SAV*** denotes the system allocated values for each parameter; ***DCV*** defines the constraint values of dependency on other service nodes.

The value sources of the same configuration parameters for the whole solution topology may differ from the partial solution topology ones. The original DCV may be changed to USV due to lacking of some dependency relationships for the partial solution topology.

C. Management

In management phase, dynamic scaling and automatic software upgrading capabilities will be enabled in the elastic infrastructure according to the real monitored performance.

As shown in Figure 1, the automatic deployment capabilities provide the flexible mechanism to build the business agility, while the horizontal and vertical scaling mechanisms are provided as 2 dimensional methods to resolve different performance tuning problems. The horizontal scaling denotes the scaling-up and scaling-down capabilities, while the vertical scaling specifies the scaling-out and shrinking capabilities.

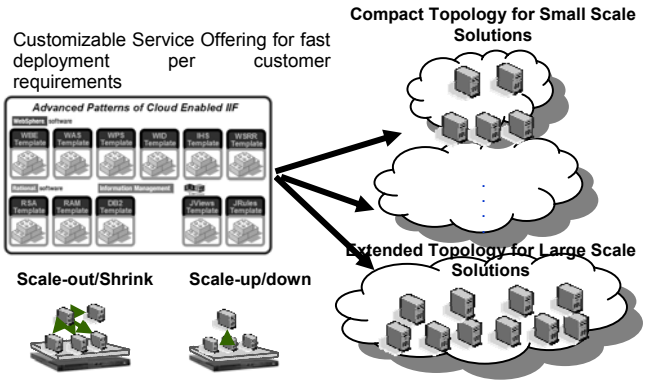

Figure 1. Cloud based lifecycle management

Scaling-up and Scaling-down denote that the resources of the running service nodes can be adjusted based on the real performance monitoring situation. Scaling-up will increase the allocation of CPU or memory into the deployed service nodes, while Scaling-down will decrease the allocation of CPU or memory resources from the deployed service nodes.

Scaling-out and Shrinking is another way to adjust the performance capability of the deployed solution instances. Scaling-out indicates that adding more nodes into an existing cluster environment, such as adding a new node to a cluster environment. Shrinking is similar but does the way contrarily when running environment is in comparably idle status, and some of the member nodes can be released from the cluster to save resource for other usage.

D. Architecture and Component

The primary architecture and components of cloud based IIF solution lifecycle management are shown in Figure 2. The main components include the Management Console, Service Offering Catalog, Resource Manager, and a provision and automation engine that is used to instantiate services on the cloud infrastructure. Management Console provides a Web 2.0 based user interface to aid the administrator to manage the cloud based solution lifecycle, with an at-a-glance view of various services' sub-views including request for the deployment, monitoring of the deployed environment, and management of the running environment, etc.

Service offering catalog contains existing pre-built and self-customized solution topologies, which are stored in XML format.

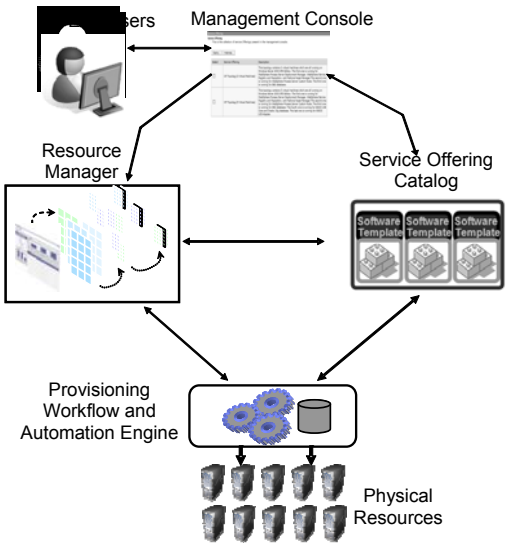

Figure 2. Architecture and Components of Cloud Based IIF Solution Lifecycle Management

Resource Manager is used to manage the resources for deployment. The Management Console invokes the Resource Manager to obtain the resource and component requirements to satisfy the provisioning of the requested service based on the selected service offering. Once these are decided, the Resource Manager and Management Console will interact with the provisioning engine together with configuration metadata to determine the currently available resources and use mapping algorithms to handle the deployment process.

The underlying IT resource provisioning engine is leveraged to execute the decisions made by the Management Console. This allows the IT resource virtualization

management to be developed and maintained separately from the other components. Since different provisioning engines from different vendors and open source projects differ in their interface and implementation mechanism [9], in order to allow the solution independent from the underlying different cloud computing infrastructures, we propose a framework for adapting the generic provisioning infrastructure.

III. IIF BUSINESS PROCESS ENVIRONMENT IN PAAS MODEL

Cloud based IIF solution lifecycle management serves as a powerful cloud infrastructure layer for IIF as a platform. Whereas, applications developed based on IIF are more important to generate value and solve real-life problems. The application developers of chemical and petroleum industry who set their mind on efficient usage of IIF still face the challenges of complexity induced by application logics weave-up based on such software portfolios. Meanwhile, IIF itself is a framework, so naturally it supports a platform in cloud not only for infrastructure automatic deployment and resizing, but also, and more importantly, for application development.

Conventionally, the development of process centric and event driven application may include process modeling, coding and testing, by leveraging a set of complex on-premise tools, which may cause relative long time for the application to go into production environment, even for a small application. As well, long learning curve of IIF specific APIs in the form of Web Service, RESTful service and Java API may also become a major hindrance to shorten the time to market. Chemical and petroleum enterprise also has requirement for rapid integration of new business system and external services to support the rapid change of supply chain, acquisition, establishment of new organization unit or branch, etc. In some cases, applications are only integration of IIF services with simple logic, which need no complex Java programming. A new approach is required to rapidly develop application by integrating IIF services, UI components, business process, business event, and database, with less workload, high efficiency and faster time to market.

Platform-as-a-Service (PaaS) is a delivery of a computing platform over the web, which enables use to create applications quickly. Addressing the shorter time to market and higher efficiency of development, IIF business process environment in PaaS model is designed and implemented to ease the workload of IIF developer in facilitating a lower cost, quicker time to market programming mode, as well as an easier integration to IIF infrastructure (shown as Figure 3). This environment is formed by a set of interrelated web based rapid on-line development tools, and in this section, we elaborate on 2 key features of them:

- Visualized programming model with integrated middleware capabilities as business process, business event , Web 2.0 UI and database;
- Cloud based application lifecycle management.

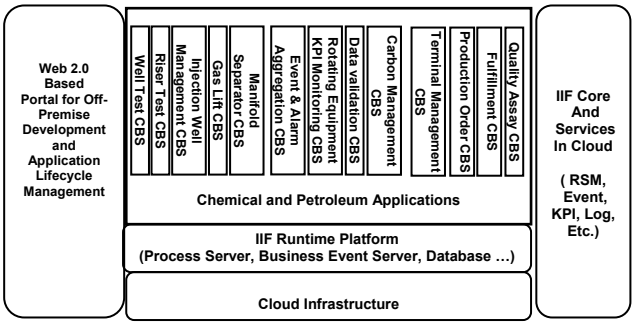

Figure 3. Overview of IIF Business Process Environment in PaaS Model

A. Visualized Programming Model for Application Development

Applications in chemical and petroleum industry usually contain logics to monitor and integrate performance data from multiple-sited plants with the aid of real-time events generated from devices and instruments. To have these data reflected in a business perspective, dashboard enabled UI is needed to present on-time or historical data. Additionally, to diagnose problem, processes to calculate KPIs are usually activated in response to the above events, which are also shown in UI pages for analysis. To meet such business requirement, software bundled to support process, event, UI and database are inevitable to challenge IIF developers' skills and development cost.

To mitigate such obstacles, we present a visualized programming model with integrated middleware to include all the above mentioned capabilities.

As shown in Figure 4, we provide a widget named "Service Assembler" which acts as a visualized business process editor. In the palette on the left, not only the basic building blocks for a general process are list in the drawer named "Integration Elements", but also reusable Web Services and RESTful Services already hosted in IIF solution runtime are list in the drawers named "RSM Web Services", "KPI Web Services" and "KPI RESTful Services". These services help IIF developers to draft any business processes which are meant to manipulate with RSM (Reference Semantic Model [10]) models and in-monitor KPIs of an IIF solution. The main canvas on the right serves as the business process modeling view, in which developers simply drag-drop composing elements from the palette and use arrows to link them together. Under the modeling view, a property view is presented to allow developer to conveniently specify configuration parameters for each elements of the process. Developer without any programming language skill can easily fulfill the task, only if he gains general knowledge of XML, WSDL, XSD and Web Service invocation.

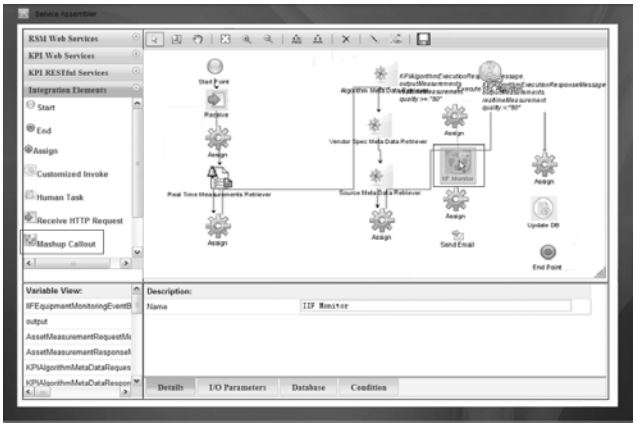

Figure 4. Service Assembler - Visualized Business Process Editor

A specialized kind of elements named "Mashup Callout" marked by rectangle in Figure 4 shows how a developer can swiftly link certain step within a process with an UI implementation. IIF application developers can realize UI logics in the unit of Widgets, and then can register them into any Widget mashup software. While "Mashup Callout" element together with a paired element "Mashup Callin" can assist to specify which Widget the process will be linked to, and what content of XSD formatted input/output parameter values should be exchanged between the process and the target Widget.

Another specialized kind of elements named "Database" is used to include off-premise database capability into process. In the property view of this element, the developers can insert basic database CIUD (create, insert, update, delete) operations visually without caring about backend database connection configuration and writing SQL statements.

The visualized programming model also has the capability to build up link between business event and process to further coincide with IIF application requirement. We allow web-based on-line business event template creation by uploading predefined event syntax in XSD format. We also allow association of created business event template with business process by matching event entries with process input parameters to form an event-driven process paradigm. For example, an equipment monitoring event which carries real time equipment diagnosed data is linked with a business process authored from "Service Assembler" which will validate the working status of this machine and check the KPI violations.

With such an integrated IIF business process environment in PaaS model, developers will dramatically shorten application development cycle, and the resulting business process is ready for further transformation to runnable format.

B. Cloud Based Application Lifecycle Management

In addition to the visualized programming model, cloud based application lifecycle management is enabled to strengthen the consumability of the whole IIF business process environment in PaaS model.

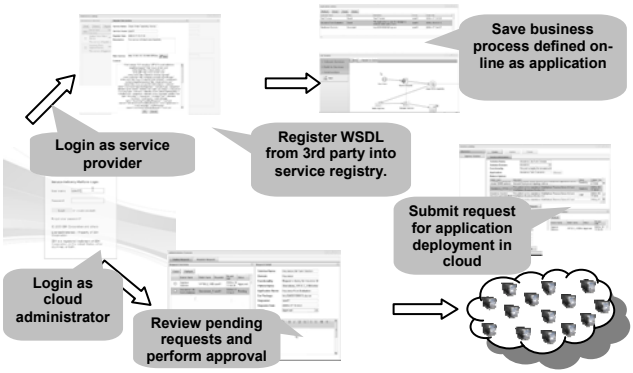

Figure 5. Cloud Based Application Lifecycle Management

As shown in Figure 5, the whole application lifecycle management capability serves 2 roles: Service provider who acts as the IIF developer to do development related affairs, and cloud administrator who performs cloud resource allocation and authorizes service providers' requests.

The application lifecycle management is incorporated as part of the PaaS model, and also involves several Widgets as web-based UI. Both the 2 roles mentioned above share the same login gate page, where after signing in, the user is routed to different UI paths. For a service provider, he is firstly required to register any external Web Services that will be further leveraged by process development. Then, he will use all web-based tools mentioned in section IV-A to develop an IIF application on line. Finally, after choosing suitable topology maintained by cloud based IIF solution lifecycle management as target deployment environment, service provider submits the application deployment request. For a cloud administrator, he will firstly be shown a list review of all pending requests from service provider, then after resource justification, he may approve or deny each of them. If approved, the application will be automatically installed onto the selected actual IIF solution and be in function after reasonable time duration. Or else, corresponding service provider will get rejection notification for request modification.

The whole role based application lifecycle management mode supports publish-subscribe and renting business model for dynamic application composition and instantiation to get better compliant with cloud management concept and spirit.

IV. IIF AS PROGRAMMABLE SAAS

The Software-as-a-Service (SaaS) concept has been defined as an improved version of the Application Service Provider (ASP) model, in which providers host and provide access to a software application over a network. The SaaS

model has evolved to a web-based application interface, incorporating other attributes such as multi-tenancy, configurability and scalability. Independent software vendors (ISVs) were then able to shift from delivering on-premise software solutions to deliver a complete software application to end-users over the Web. Enterprise SaaS, aligned with elastic infrastructure and PaaS, provides the brand new business model and efficient way for user to benefit more from cloud computing by leveraging cloud enabled IIF in both private and public cloud.

A. IIF as Internal Programmable SaaS

Chemical and Petroleum companies are always large enterprises with a large number of organizations including upstream, downstream and chemical with numerous application and data types. The homogeneous organizations, such as branches in different regions and countries have a large number of tenants with similar requirements for the same process and application type, or only with minimal difference. For such enterprise, the IIF based internal SaaS hosted in a private cloud will significantly reduce the cost for each organization unit to build their own IT system and multiple licenses of the same software. With enterprise's moving to SaaS, different organization units could share both the infrastructure and applications which provides unparalleled superior in solving the solution release and version control problem, which have plagued the enterprise software maintenance for decades. As well, the centralized IT management and application development model will ensure the high quality of application and availability of system.

Mergence and acquisition activities remain common, and most companies want to standardize their processes and operate globally. Typically, companies that have recently undergone mergence and acquisition activities have to operate on duplicate, suboptimal supply chains that are not demand-based. Often, companies have inaccurate information about how these supply chains operate. Yet, in the face of worldwide uncertainty about volatile crude oil supply and the availability of refined product and prices, such companies need to make fast, well-informed supply decisions. Hosting all the subsystems used by the different organization units rooted in the same cloud environment will significantly improve the efficiency to manage dynamic change for acquisition, mergence and integration of the internal supply chain.

B. IIF as Public Programmable SaaS

With public SaaS model emerging, new opportunities appear in the chemical and petroleum industry for market place of chemical and petroleum services and dynamic integration of the external supply chain.

On one hand, chemical and petroleum supply chain is so complex that no single vendor could provide the entire applications along it. IIF based applications naturally select its market place in the cloud, where these applications can work together, and services exposed from them can be sold separately. On the other hand, IIF is a comprehensive but relative complex solution for small and middle scale enterprises who act as nodes in the supply chain. So IIF could be naturally transferred to SaaS to be used in pay-by-use usage mode, and for small and middle scale enterprise to get rid of the trouble to maintain those complex hardware and software environment. Plus PaaS model introduced in section III, the coupling with cloud provides the dynamic unit as service implementation that could be rapidly developed, deployed and scaled, as well as the new business model.

As shown in Figure 6, different enterprises are integrated into a smart supply chain in the cloud with following roles:

- *Owner of the cloud that maintain the infrastrcuture and business model for IIF as programmable SaaS*
- *Application Provider that develops applications publishes service in the service market place*
- *Application Subscriber that subscribes the application and services as well develops the applicatons for internal use or publication in the service market place.*

It matches the initial intent of IIF to build a responsive, integrated supply chain that operates in real-time with suppliers, partners and customers. It is a highly complex proposition that requires a unique combination of consulting, technology and service skills, to optimize demand and supply planning for rapid returns and immediate impact. IIF as a Service provides a platform where upstream enterprises, downstream enterprises and chemical enterprises working together to facing the rapid changing environment. Meanwhile, as we know there is a limited member of large enterprise covering the whole chemical and petroleum value chain. IIF as a Service could optimize the inner supply chain and departments to make it agile and more efficient.

IIF in SaaS model provides a new delivery model, in which the upstream/downstream participates are able to concentrate on their own core business and gain help from IIF service with pay-by-use without caring about infrastructure level hardware and software complexity. Each participator of the entire supply-chain interacts with IIF as a Service with the focus on its own service context. Below is a sample illustrating how and why IIF as a Service enhance the supply chain of chemical and petroleum industry.

Generally, supply chain means different for each enterprise. IIF as a Service benefits each enterprise from internal and external of supply chain. Enterprises could dynamically integrate the nodes into the supply chain, add new business unit, and rapidly change the supply chain according to the changes from supply chain context. With IIF acting as a cloud enabled supply chain hub, the enterprises could exchange their information timely and efficiently.

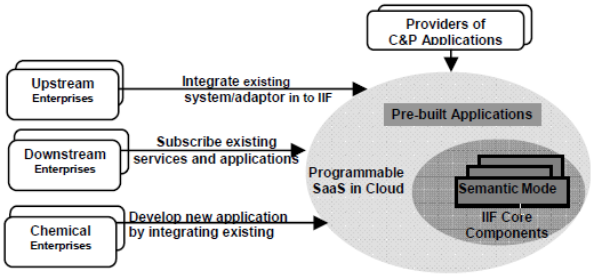

Figure 6. IIF as Programmable SaaS in Private or Public Cloud

V. CONCLUSION

Business agility is of vital importance to chemical and petroleum industry, especially in rapid response to diagnose and exchange of real-time information and other relevant data sources. From IT perspective, cloud computing is an emerging and evolving field. It is foreseeable that solutions will be developed in rapid succession into the forms as elastic infrastructure, PaaS and SaaS, and certain cloud enabled investments that will have implications for version migration and integration.

In this paper, we investigate how the new delivery models brought about by cloud computing accelerate the improvement on the efficiency within integrated information framework for chemical and petroleum industry. From elastic infrastructure aspect, the capabilities and implementation mechanism of cloud based IIF solution lifecycle management is presented. From application development perspective, business process environment in PaaS business model is introduced. Finally, the value and position of IIF as programmable SaaS is discussed. We demonstrate how the cloud computing technologies and architectures significantly enhance the capability and agility of IIF in chemical and petroleum industry.

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