Collaboration Algorithms between Intermediaries for Supporting Flexible Supply Chain Management

Mohd Izzuddin Mohd Tamrin, Tengku Mohd Tengku Sembok, and Mira Kartiwi

***Abstract*—**The supply chain group consists of members from various locations in the network working together to deliver services to the client. Integration challenges remain as main issue for the group to create more flexible processes and allow modification to be made to the current and global pre-planned processes for the entire supply chain members in the group. The authors introduce Integrative Information Management Architecture (IIMA) running on collaboration algorithms which create semi automated intermediary processes to support management team address integration challenges. The collaboration algorithms are design to go through five main phases in order to continuously monitor and detect any deviations from the processes currently running at the vacinity of the members. The functionalities of existing systems across the members in the group are wrapped and introduce in the IIMA as services. This is to facilitate process restructuring by addding or dropping the required services into the global execution schedule. The authors had develop the prototype of the IIMA and evaluate it with three other related systems in a simulated environment. These systems simulated to support customization processes with common supply chain problems at the beginning and ending stages of that processes. The results demonstrate that the IIMA has the most stable performance in supporting the shared processes when stoke by the problems at both stages of the processes.

***Keywords*—** Collaboration algorithms, integrative architecture, semi-automated intermediary processes.

I. Introduction

THE supply chain activities are very important contributor to the Gross Domestic Product (GDP) of a country. The member in the supply chain network offered specialized services and products to the other members in the network. They work together temporarily or permanently to create the right services and products to their customers. The management of the shared processes between these members is of high importance. The failure for merely one of the member to perform adequately as planned can create severe disruption to the current shared processes for the entire supply chain group. And ultimately the supply chain group incurred administration costs for not being able to deliver their services on time.

This signify the importance of collaboration between the members in the supply chain group to work together in order to achieve their common goal. However, integration issues limit the level of collaboration between the members in the group. Firstly, the information stored in the servers do not correctly reflect the processes executed on the ground [1][2][3]. The inaccuracies arise from errors in manual loading of the data into the systems may affect decision making for the supply chain group in a negative way. Bad decisions made can affect the final outcome of the shared processes and can directly incurred additional costs to set things right.

In addition to this, the information on the progress of the processes shared at their corresponding partners across the supply chain group are very limited [4][5][6]. The information are very high level such as revealing only the status of the progress but do not touch on lower level information such as the operations involved in the processes, the types of inputs required and difficulties faced during the executions. The degree of information sharing between the members will influence the level of flexibilities in the shared processes in term of process restructuring. This information are important for the group to make the necessary preparation at the right time in order to overcome common problems in the supply chain such as delay in transportations [7] and misplace items [8].

These two problems distinguished between uncontrolled and controllable events that can impinged on the middle of the executed shared processes across the supply chain group. Transportation delays can occur because of bad weathers and road accidents which will be difficult for the supply chain group to avoid whereas misplace items can still occur even with manual checking procedure in place. The situation will become worst when the supply chain members are working in isolation [9][10][11]. The systems need to be integrated and be able not just to communicate with each other but up to the point of controlling the operations of their partners. There is a

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Mohd Izzuddin Mohd Tamrin is with the Department of Computer Science, International Islamic University Malaysia, Gombak, 50728 Selangor, Malaysia (e-mail: izzuddin@iium.edu.my).

Tengku Mohd Tengku Sembok is with the Department of Computer Science, International Islamic University Malaysia, Gombak, 50728 Selangor, Malaysia (e-mail: tmts@iium.edu.my).

Mira Kartwi is with the Department of Information System, International Islamic University Malaysia, Gombak, 50728 Selangor, Malaysia (e-mail: mira@iium.edu.my).

need to move beyond supporting one form of shared processes for the group and being able to change their processes at will.

This ability is very important for the supply chain group to react adequately to common problems mentioned above by restructuring the current processes with an alternative processes which could overcome those problems. In this paper, we introduce intermediaries which provide semi automated assistance for the supply chain members to support for more dynamic shared processes. The organizations of these intermediaries are called the Integrative Information Management Architecture (IIMA). Collaboration algorithms have been designed to run on the IIMA whereby it dictates the behaviours of this integrative architecture into five main phases.

The authors believe that by creating RFID services from the manipulation of the data retrieved from the RFID networks can provide adequate process monitoring mechanism. These data need to be transformed into process level information in order to make sense of the current executed shared processes across the supply chain group. Support models are created and embedded into IIMA and served as maps to provide insight into the problems, finding the suitable alternatives based on characteristics of the problems and the constraints for the processes selected as alternatives. These support models are created as XML documents to provide the universal accessibility to the models and provide the ease of model manipulation based on the context of the local supply chain operations.

Easy model manipulation is very important consideration in the IIMA because a different local supply chain segments require a different content of the support models to reflect the local operations. Lastly, the existing supply chain systems across the group are wrapped into independent supply chain functionalities and advertise as services in the IIMA. The reason for this is to allow a more flexible process restructuring by dropping unwanted processes from the list of executable processes and adding the required processes into the list. In addition to this, the RFID services can be mixed with supply chain services to make up the processes for a dynamic supply chain management that can react to common problems in the supply chain. In the subsequent sections, the authors will present the related works, followed by the overview of the IIMA and formulization of the support models. Next, the collaboration algorithms will describe the interactions between the components of the IIMA. Following this, the evaluation of the IIMA prototype, analysis and discussion will be presented. Lastly the authors conclude this paper.

II. Related Works

The works conducted in RFID based systems are growing steadily in various research fields. From our survey in the RFID based system across various research fields, the motivation for these systems are threefold: automate identification [12][13][14][15], to facilitate the management of processes [16][17][18][19] and to facilitate system learning [20]. As for the first motivation, the data retrieved from the RFID networks contained a unique identification number which refer to a specific taggable item. The important things involved directly with the processes can be retrofitted with RFID tags. These include the people, equipments and materials used in the processes.

The data retrieved are already in a digital form and this can ultimately reduced the errors of manual data transformation. Inaccurate information can reduce the effectiveness of any decision making. Another important feature in this category is the ability to search for specific thing in a large crowd of very similar things in term of their appearance. The time taken to manually search for things in the processes can be reduced to increase the efficiency of the processes. The second motivation covers from simple to more complex management of processes. As for the support for simple processes, the systems are utilized to continuously monitoring and tracking the behaviours of the tagged things within a certain period of time.

Based on the patterns of their behaviours, discrepancies can emerged by comparing them with the original planning. The automatic vehicle location system proposed in [21] eliminate the need to keep the existing fault process for cargo handling simply by introducing automated checking points at the loading bay before the items are transfer into the trucks for delivery. As for the complex processes, the systems streamlined pre-planned processes triggered by the events captured by the readers. Combination of data from the readers based on context specific rules can create the meaningful events understood by the systems. The third motivation is to utilize data from the readers and through reasoning techniques these systems can make better decisions on the next iteration of their operations in the similar environment context.

The authors are interested in the first two design challenges of RFID based systems and start to focus the survey on the area of supply chain management. There are several issues emerged from this survey. The RFID mean time architecture [22] extracted only the time segment of the data retrieved from the RFID networks. The analyses are based on the average time for the processes to get completed in order to find any bottleneck in any of part from the processes. In contrast, the customization system [23] employed a more sophisticated analysis of the data by introducing the concept of network coefficients. The network coefficients are designed to inform the group on different aspects of the supply chain activities merely from the inflow and outflow of tagged things.

However, both of these architectures do not provide information at the process level. The information does not inform the system on the actual processes that are current executed but instead inform the system on level of activities being executed. The model based monitoring system [24] produce process level information with the creation of constraints based component model. Tagged things are included in their model as components with the values of their attributes for every state in the processes. Based on the current values of the attributes retrieved from the RFID network, the system keeps track of the state for the processes. The authors adopt a simpler approach by matching the events created through RFID services against the instructions based on the support models.

These support models are context specific and can be uploaded into the IIMA. The layout of the facilities from varies between the members and the authors dissected the facilities according to independent process unit in order to develop the support models. This approach of dissecting the facilities is similar to the work done in [25]. Up to this point, the RFID based system provides support for continuous monitoring but authors had not found any mechanism to support flexible process restructuring. For this reason, we started with the survey on component services [26][27][28][29]. The processes can be decomposed into smaller and independent processes. These independent processes are loosely coupled and offered as services by the members involved in the shared processes.

The services from across the members in the group can be integrated to create shared processes. Next, the authors survey component services based systems in the supply chain management. There are two approaches in the implementation of component based systems: service invocation [30][31] or module construction [32]. The differences between these approaches are service invocation let the member responsible for the advertised services execute the processes whereas module construction let the appointed member to execute the entire processes but the coding for the processes can be extracted from various sources. The authors are incline toward the service invocation approach. The collaborator system [33] employed a portal to create global planning for the integration of the shared processes across the members in the group.

The planning contains web portlets which described the services to be invoked at the member side. In comparison, the IIMA wrapped functionalities from the existing systems and advertise them as services instead of developing the services from scratch for the use of planning in the portal which is similar to the approach employed in [34]. However for the component service based systems, there are no mechanisms for monitoring the processes but this can be addressed with the RFID based systems. In addition to this, the bio-disease tracking system [35] offer estimation of the objects tracked are affected by disease as an additional functionality apart from the functionalities generated via the existing systems. Conversely, the IIMA offer vital functionality such as detecting process deviation by manipulating the data generated from the readers as RFID services. The integration of the design aspects from both systems enables the authors to formulate the IIMA. The organization of the IIMA will be presented in the following section.

III. INTEGRATIVE INFORMATION MANAGEMENT ARCHITECTURE

A. *Overview of Architecture*

The IIMA is position between the RFID networks and the supply chain existing systems as illustrated in Fig. 1. This architecture utilize data from the RFID networks and the functionalities from the supply chain systems to provide the support required for a more flexible supply chain management. The architecture can spead across every member in the supply chain group and the extension of its coverage depending upon the availability of the infrastructure across the group. If the RFID network of readers are available on only selected members in the group, the coverage of its support limit to only these selected members.

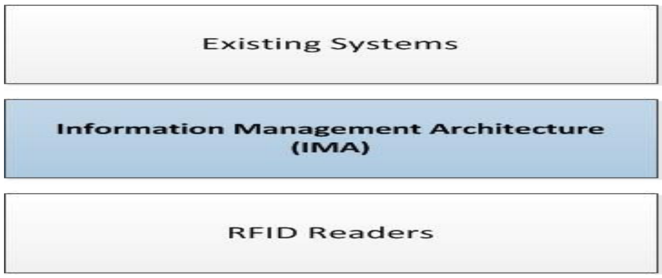


Fig. 1. Overview of the Architecture

The overview of the architecture is very important to understand the requirements for implementing the IIMA, the scope of what the architecture can support and what it cannot support. The example for this case is that before the supply chain group can proceed with the implementation of the IIMA, they must first establish and get the RFID networks up and ready to scan data. In term of the scope, the architecture overview made it clear that the IIMA does not generate the raw data but merely pump in those data from the RFID networks. In addition to this, the IIMA merely wrapped the functionalities from the supply chain systems and offer them as services to allow a more flexible integration of services across the members in the supply chain group but not create new supply chain functionalities.

B. *Organization of the Architecture*

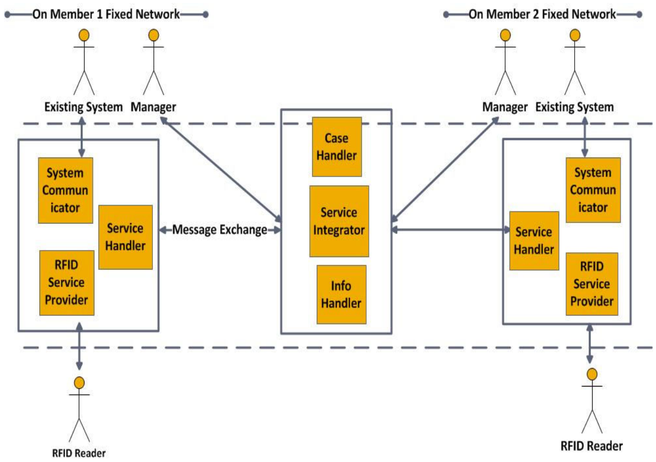


Fig. 2. Organization of the Architecture

The organization of the architecture is describe in Fig. 2. The architecture composes of six main components: the system communicator, RFID service provider, service handler, service integrator, case handler and information handler. These components are divided into sets and incorporated as the main system and the subsystems. There can be only one main system with many subsystems. The subsystems consist of system communicator, RFID service provider and service handler whereas the main system consisted of the service integrator, case handler and information handler.

The subsystems are installed on distributed servers across the network of every member in the supply chain group. They are responsible to perform continuous monitoring of the shared processes at its local vicinity. On the other hand, the main system is installed on the centralized server and is dedicated to facilitate for process restructuring in the case of common problems emerged from the current processes. The relevant subsystems send the information regarding the problems detected in its local vicinity and trigger the main systems to response. In the following, the responsibilities of these components will be described.

RFID Service Provider: Responsible to provide RFID services to the service handler. RFID services are generated from the manipulation of data pushed by the RFID networks. The data retrieved from RFID networks contain very basic information that are not process level information such as the unique identification of the tagged things, the timestamp recorded when the data was captured and the identification of the readers making the reading. Combination of information from other sources with these data can create process level information. For our case, by design the local vicinity are decomposed into several segments based on independent supply chain operations and specific readers are assigned on that segments. From the reader identification number the location can be revealed, and from the location, the processes can be revealed. The association from the tag identification number, reader identification number, the location and processes can describe the information required at the process level.

Service Handler: Serve as the middleman between the local subsystems and the main system. The service handler is responsible to detect deviation in the processes at its local vicinity. It matches the event generated from RFID service provider against the instructions in the global planning for the shared processes. Any form of discrepancies detected, trigger it to refer to the problem model. Problem model contain the information on the type of common problems experience by the group in their local vicinity. Based on the events generated from RFID service provider and the instructions given, problem model can determine the type of problem the group is facing at that point in time. The problem identified will be sent to the service integrator on the main system. In addition to this, the service handler required to create local schedule for services execution based on the global planning. It invokes the system communicator and the RFID service provider using the local schedule.

Service Integrator: Serve as the middleman between the main system and the local subsystems. The service integrator is responsible to restructure the current shared processes based on the problem determined by the local service handler. It gets in contact with the case handler to seek for alternative processes which could overcome that problem. Next, the service integrator consults the management team to get their approval on the alternative processes. The management team consists of prominent people from each member in the supply chain group and has the authority to make changes to the current processes. After the approval, the service integrator get in contact with the information handler to verify whether the alternative processes meet several important constraints defined by the group before uploading them into the list of services for execution (LSS).

Case Handler: Employ the case model to determine suitable alternative processes to overcome the problem identified by the local service handler. Based on the type of problem, the events generated by the local RFID service provider in the list of events (LE) and the instructions from global planning, the case handler will navigate through the case model by asking a series of questions which lead to the alternative processes. The extraction of the alternative processes or solutions will be sent to the service integrator to be presented to the management team as recommendation.

Information Handler: The information handler is responsible to verify the approved recommended solutions against the process constraints set in the information model. The alternative solutions will be analyzed in various aspects of service executions such as the inputs required for the services, the member responsible for the execution of the services, the outcome and goal of these services. Based on this information, the information model will be utilized to determine whether the alternative solutions had violated any process constraints. It will check whether the services are assigned to the right member based on its role for the group, this member is still active in the group, and this member has the authority to access the required information for the service executions. If there are no violations in the process constraints the alternative processes are granted the permission for executions.

IV. COLLABORATION ALGORITHMS

The collaboration algorithms are design to govern the interactions between the six main components of the IIMA. These algorithms are install and run on the main and subsystems of the IIMA to undergo six main phases to support flexible supply chain management. These phases include the vigilant, deviation, alteration, validation, switch over and registration phase. In the following subsections, the authors present the high level description these phases using pseudo-code except the registration phase because that phase is design for future study.Table 1 below describe the notation used in the algorithms.

Table 1. Notations in the Collaboration Algorithm

Variables	**Description**
LD	List of Basic Data
LE	List of Events
LT	List of Transactions
LI	List of Instructions
LP	List of Problems
LAS	List of Alternative Solutions
LOR	List of Results
LC	List of Constraints
LSS	List of Schedule Services
LTM	List of Team Members
LFM	List of Flag Members
Sub-Components	
ri	Reader Interface
rp	RFID Provider

evm	Event Manager
exm	Execution Manager
ci	Case Interface
pm	Process Manager
cmg	Case Manager

A. Vigilant Phase

```
Variables: socket, LD, LE, LOR, memberNum, loc, oper
while(true):
  try :
    Socket socket = rfidServer.accept();
    SubSystem(socket);
SubSystem:
LOR = rpObj.getCurLink();
if (LOR != memberNum), then:
  LOR = rpObj.writeLink(memberNum);
else:
  LE = riObj.startMonitor(socket);
RFID Service Provider:
for (int i=0; i<LD.getSize(); i++):
  loc = findLoc( readBean.getReaderID(LD.get(i)));
  oper = findOper(loc);
  LE = createEvent(readBean, loc, oper);
```

Fig. 3. Vigilant Phase: High Level Description

The collaboration algorithms start with the vigilant phase as shown in Fig. 3. In the vigilant phase the RFID server continuously listen to incoming basic data from the local RFID network of readers. These data are stored in the list of data (LD). The data from the LD are extracted and check for their current links through one of the subcomponents of RFID service provider, the RFID provider. The current links retain the history of movements for the tagged things and are represented as chains of member numbers. If the local member number does not exist in the current links, the local member number will be appended at the end of the current links. Next, the reader interface, another subcomponent of the RFID service provider, begins initiating the transformation process of basic data into process level information by invoking the "startMonitor" method.

The authors have designed local vicinity of every member in the group as segments of independent processes with their designated readers. Based on this, the RFID service provider can get process level information by associating the designated readers with their location, and in turn, the location reveals the independent processes. The transformation necessary to be carried out because the data from the LD are in their basic form with merely information on the unique identification of the tagged things, timestamp recording the moment in time of data capture and the reader identification of the designated reader performing the data capture.

B. Deviation Phase

In the deviation phase as describe in Fig. 4, the event manager, one of the subcomponent for the service handler is responsible to initiate deviation detection for local processes. For every event in the list of events (LE) are compare with their corresponding instruction and transaction from the list of instructions (LI) and list of transactions (LT) respectively. The LE is generated from the previous phase from the transformation of basic data to process level information. In contrast, the LI are derived from the global planning across the supply chain group and the LT are derived from the invocation of local services by the system communicator.

```
Variables: LP, LE, LT, LI, LOR, clientMain, pw,
 hostName, portNum
SubSystem:
while(curEvent == false):
LOR = evmObj.detDeviation(LE);
  if (LOR == true), then:
    clientMain = new Socket(hostName, portNum);
      pw = new
      PrintWriter(clientMain.getOutputStream());
      pw.println(LP);
  else:
    evmObj.insertEv(LE);
Service Handler:
for (int i=0; i<LE.getSize(); i++):
  if (LE.getLoc()==LI.getLoc()&&
  LI.getLoc()==LT.getLoc()), then:
    LOR =True;
  else:
    LOR = False;
```

Fig. 4. Deviation Phase: High Level Description

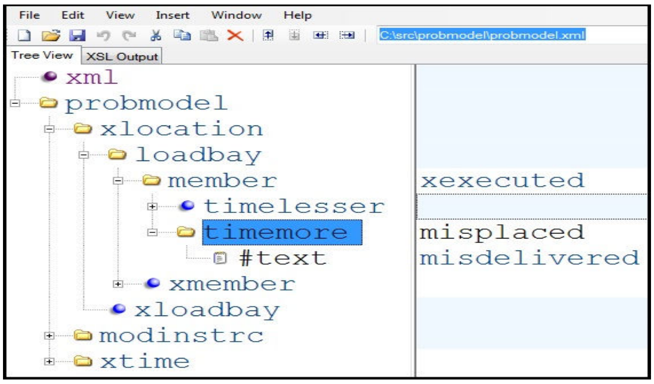


Fig. 5. Problem Model: Fraction of XML Data

The service handler searches for mismatch in the time and location between (1) the instruction from the global planning, (2) the services that were executed by the system communicator, and (3) the event captured by the RFID service provider. The results are stored in the list of results (LOR). If there are no deviation detected, the event manager store the event in the centralize database by invoking "insertEv" method. Conversely, if it detected deviation in the local processes, the event manager began to determine the type of problem with the aid of the problem model depicted in Fig. 5. Using this model, the event manager start at the root node and start to navigate through the children nodes based on the mismatch identified earlier. For example, the event manager starts exploring the "xlocation" instead of "xtime" and "modinstrc" because there are differences in the location of the event and the instruction.

C. Alteration Phase

```
Variables: LP, LSS, LAS, LOR, LTM, LFM,
socket, main Server
while(true):
  try :
    Socket socket = mainServer.accept();
    MainSystem(socket);
MainSystem:
LAS = ciObj.initiateChange(LP);
SubSystem(Running in Parallel):
for (int i=0; i<LSS; i++):
  LOR = evmObj.verifyPrevEv(LSS.get(i));
  if (LOR == true) , then:
    exmObj.prepExec(LSS.get(i));
  else:
    break;
Service Integrator:
while(LFM==false):
  LAS = cmgObj.getAlternative(LP);
  for (int i=0; i<LTM.size(); i++):
    LAS^temp = reqAlteration(LTM.getMember(i),
    LAS);
    if (LAS^temp == LAS), then:
      LFM = true;
    else:
      LFM = false;
LAS = LAS^temp;
```

Fig. 6. Alteration Phase: High Level Description

In the alteration phase as describe in Fig. 6, the main server continuously listening for local service handler to trigger process restructuring by sending list of problem (LP). Case interface, one of the subcomponent of the service integrator is responsible to initiate the process change by invoking the "initiateChange" method. At the same time in the local subsystem, the event manager verify whether the previous events had been executed before allowing the execution manager to proceed with the next services in the local list of schedule services (LSS). If the event manager had not updated the previous event in the deviation phase due to process deviation, the remaining local processes will be halted and allow the service integrator to take over with alternative processes.

The service integrator begins by consulting the case manager to make recommendation on the alternative processes based on the LP. The recommendations are stored in the list of alternative solutions (LAS) and forwarded to each member listed in the list of team members (LTM). Each member in the list is requested to make modification to the LAS by invoking the "reqAlteration" method. The service integrator access the similarity between the recommended solutions and the amended solutions. If they are the same, the member will be flagged as true in the list of flagged members (LFM). This process of flagging will continue but to access the similarity of the solutions between these members. Once there are no more modification made on the common solutions and the entire flag for the members in the LFM had turned to true, the validation phase begin.

D. Validation Phase

```
Variables: LAS, LOR, LC
MainSystem:
while(LOR == false):
// loop is located before entering the alteration phase
LOR = ciObj.verifyCase(LAS);
Information Handler:
infoDoc = docBuild.parse(in);
LC = getConstraints(LAS);
for (int i=0; i<LC.size(); i++):
  xPath = findEquivalence(LC.get(i));
  nIterate =
  XPathAPI.selectNodeIterator(infoDoc,xPath);
  nPoint = nIterator.nextNode();
  val =  nPoint.getFirstChild().getNodeValue();
  if  (val == LC.get(i)), then:
    LOR.set(i) = true;
  else:
    LOR.set(i) = false;
```

Fig. 7. Validation Phase: High Level Description

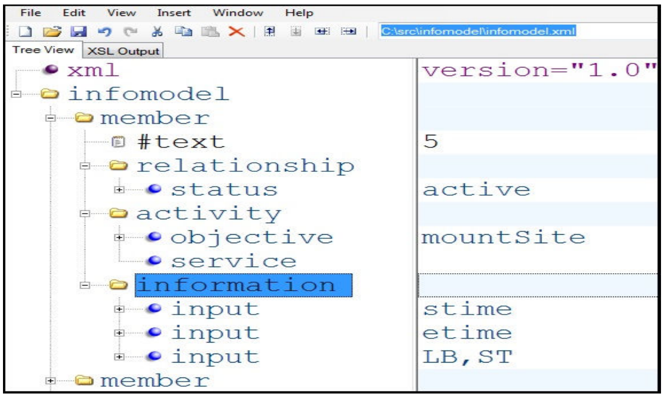


Fig. 8. Information Model: Fraction of XML Data

In the validation phase as describe in Fig. 7, the information handler is responsible to check whether the proposed alternative solutions violate any of the process constraints defined in the information model. The information model depicted in Fig. 8 describes the relationship of each member toward the supply chain group in term of their current status, roles and accessibility of information. Based on the alternative solutions, the information handler derived process constraints by invoking the "getConstraints" method and stored these constraints in the list of constraints (LC). In this example, the constraints are "member-5", "status-active", "objective-mountSite", "input-stime;etime;LB". For every constraint in the LC, the information handler employs the information model to find its corresponding value by invoking the "findEquivalence" method.

The information model initially is created in a XML document and in this algorithm we created the Document Object Model (DOM) for the information model as "infoDoc". This is to allow XML manipulation with the APIs provided in the library and Xalan package is used to evaluate XPath expression. If there is match in the value from the information model and the constraint in the LC, the LOR store true. At the end, the entire value of the LOR will be evaluated and depending whether the alternative processes have met the constraints set in the information model, the alteration phase may need to be revisited.

E. Switch Over Phase

```
Variables: AS, LAS, LAS^partial, LSS, LOR,
probIndex, refNum, memberNum
MainSystem:
 LSS.remove(probIndex);
  for (int i=probIndex+1; i<LSS; i++) :
    LAS.add(LSS.get(i));
 while(LAS != null):
  for (int j=0; j<LAS; j++) :
   if(j=0), then:
     AS = LAS.get(j);
     refNum = AS.getMemberNum();
     LAS^partial = LAS.get(j);
   else:
     AS = LAS.get(j);
     memberNum = AS.getMemberNum();
   if (memberNum == refNum), then:
     LAS^partial = LAS.get(j);
     LAS.remove(j);
  pmObj.execPartialCase(LAS^partial);
  while(LOR==false):
    LOR = evmObj.verifyPartialCase(LAS^partial);
```

Fig. 9. Switch Over Phase: High Level Description

In the switch over phase as describe in Fig. 9, the service integrator is responsible to restructure the global services based on the alternative processes derived from the previous phases. The previous global list of schedule services (LSS) contains the entire services scheduled for execution that make up the shared processes for the entire supply chain group. In order to make the necessary adjustment, the service integrator removes the deviated services from the LSS by invoking the “remove” method and supplying the problem index found in the LP. Next, the remaining services from the global LSS are extracted and appended into the end of LAS. These LAS are derived from the previous phase. Up to this point, the complete newly structured global planning is available as LAS.

In order to delegate services to the local service handler, the LAS are decomposed into several $LAS^{partial}$. The decomposition is carry out by segregating these services based on the same member number available from the alternative solutions. The services that have already been group into $LAS^{partial}$ will be removed from the LAS. This process of segregation will continue until the LAS there are no more services left in the LAS. The process manager, one of the subcomponent of the service integrator is responsible for managing the execution of the entire $LAS^{partial}$. It delegate the $LAS^{partial}$ to local service handlers in sequential order and wait for the completion of the execution at the first service handler before proceeding with the next execution at the second service handler.

V. SIMULATIONS AND RESULTS

A. Simulation Environments

The authors have developed a prototype of IIMA to prove that the integration issues in which affected more flexible supply chain management can be addressed. There are 2 servers created to implement a local subsystem. The functionalities of the RFID service provider and service handler are split into two of these servers. One of the server consists of the RFID service provider and service handler to perform continuous data transformation and deviation detection respectively. In contrast, another server is configure to perform other RFID services and the creation of local scheduling of services respectively.

The system communicator is installed in the second server. Based on this, there are 12 servers created to implement the local subsystems for the manufacturer, service integrator, specialized partner 1, specialized partner 2, the client and logistics. In addition to this, there are another two servers created for the main system and centralize database. The main system consists of the service integrator, case handler and information handler. Simulation enviroments are design to test the prototype and the combination of simulation dimensions describe below make up the simulation settings:

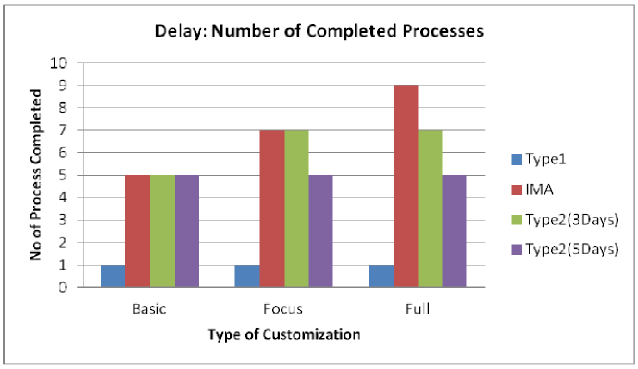
Dimension 1 – With IIMA Support: Utilize the capabilities of the IIMA to support customization processes. An extensive elaboration on the IIMA had been discussed in the previous sections.

Dimension 2 – With Alternative Supports: The authors introduce three more related systems based on the reviews from existing systems. The characteristics of these systems are extracted and the IIMA had been amended to work according to these characterstics. The first system posses the ability to perform continuous monitoring of the shared processes but there are no means available for process restructuring. In contrast, the second system posses the ability to restructure the shared processes with the component services technique but there are no mean available to get instant update on the status of the shared processes. For this reason, there will be delays for system 2 to react to the problems in the supply chain processes. The authors has define the delays to be 3 days for system 2. In addition to this, system 3 posses the same ability as system 2 but instead of 3 days delay, the authors increase it to 5 days delay.

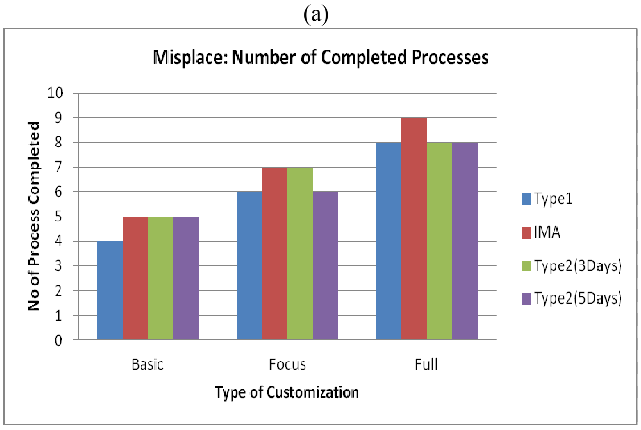
Dimension 3 – Customization Processes: This define the shared processes carry out by the members in the supply chain group. The objective of these processes is for the supply chain group to work together and produce e-commerce solutions for the client. There are three types of e-commerce solutions: basic, focus and full-fledge. The types of e-commerce solution are interrelated and form a hierarchical relationships between them. For example, in order to complete full-fledge customization processes, the supply chain group has to undergo the customization processes for the first two types of e-commerce solutions. And to complete the focus customization processes require the group to first complete the basic customization processes. Not the entire specialized partners are involve in the customization processes and the involvement depends on the types of processes required. In addition to this, there are two tracks available for each type of customization processes which allow the support for high end server and low end server.

Dimension 4 – Common Disruptions: The objective of incorporating common disruptions into the shared processes is to test the capabilities of the IIMA and the other three support systems handling process restructuring. The authors introduce two types of common process disruptions: transportation delay and misplace items. Tranportation delay occur at earlier phase of the customization processes whereas the misplace items occur at the ending phase of the customization processes. The reason for introducing these disruption is to observe the differences in the reaction for those supports. The transporation delay has many more remaining services whereas the misplace items has very little services left for execution.

B. Results



(a)

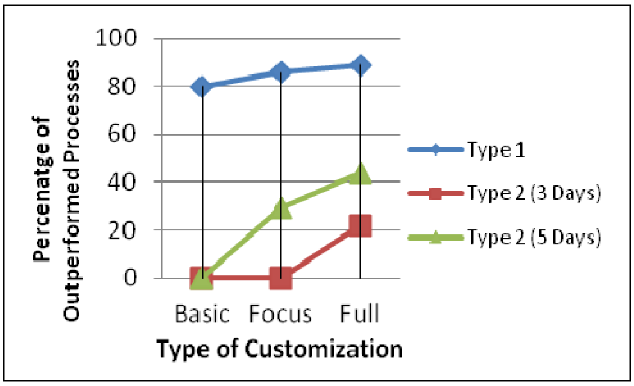


(b)

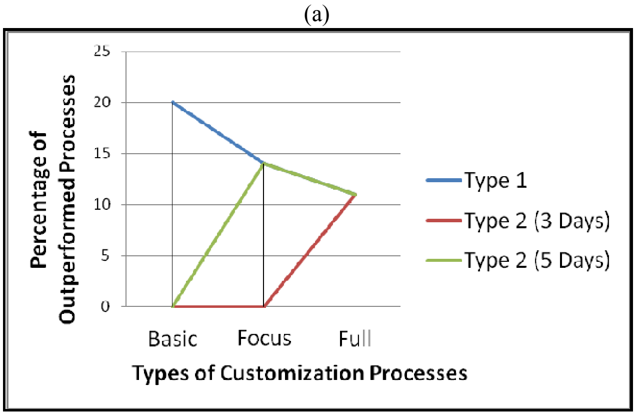
Fig. 10. Number of Completed Processes: (a) During Transportation Delay (b) During Misplace Items

In this section, the outcome for the four systems in supporting the customization processes will be presented. Based on the simulation dimensions describe above, the authors are comparing the performance of these four systems including the IIMA to complete the entire customization processes within the pre-defined time frame, which is 10 days per cycle. The number of processes involve per cycle in the basic, focus and full-fledge type of customization processes differs, but increasing in the number of processes, as it move from basic across to full-fledge.

The number of subprocesses for basic, focus and full-fledge are 13, 17 and 21 processes respectively whereas the number of main processes are 5, 7 and 9. There are two track of the processes for high end server and low end server but the number of processes are the same for both tracks. Moreover, as the number of processes increases the number of hours require to complete them increases. The number of hours for executing the basic, focus and full-fledge are 108, 152 and 200 hours respectively. Depending on the types of customization processes, there are buffers in hours which could be utilize by the four systems to make changes to the current processes in order to overcome the common supply chain disruptions.



(a)



(b)

Fig. 11. Percentage of Outperformed Processes: (a) During Transportation Delay (b) Misplace Items

The available buffers are subject to the number of days allocated by the supply chain group for each cycle of the customization processes, as for this simulation, it is 10 days. The number of available buffer in hours for basic, focus and full-fledge are 136, 88 and 40 hours. Fig. 10a describe the number of process completed from the support provided those four systems across the three types of customization processes. The number of process manage to complete by the system 1 is one process for the entire types of customization processes. The reason for this is that transportation delay occurs right after the servers are manufacture and need to be delivered to the service integrator for the customization of the IT solutions but system 1 has no capabilities to overcome the current processes and just wait for the transportation.

In contrast, system 2 with 3days and five days delay are in par with the IIMA at the beginning but started to deteriorate in their performance at the focus customization processes for system 2 with three days delay and at full-fledge customization processes for system 2 with five days delay. The reason for this is because as the number of processes increase the number of buffer in days decrease, and with a high delay in days made it not possible to restructure within the time frame. Fig. 10b demonstrates the results for the support of these systems during in the delivery of the customized e-business solutions to the wrong part of the client building. The performances between these four systems are very close when the problem occurs at the end phase of the shared processes.

	Systems	N	Mean Rank	Sum of Ranks
Tasks	3.00	20	10.50	210.00
	4.00	20	30.50	610.00
	Total	40		

(a)

	Tasks
Mann-Whitney U	.000
Wilcoxon W	210.000
Z	-6.245
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

(b)

Fig. 12. Mann-Whitney U Test: (a) Mean Rank (b) Test Statistics

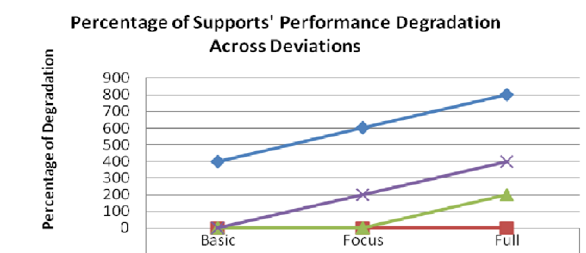
The reason for this is because the remaining number of process cut down to one starting from the point the problem impinged on the shared processes. However, the trend is similar to the previous case, when the shared processes are impinged with problem at an earlier phase of the processes. System 1 has failed to react to the problems with alternative processes and remained still until the end of a process cycle. In contrast, the system 2 with three days delay start to deteriorate in performance on the focus customization processes because of its 5 days delay constraint in reacting to the problem exceeded 3.6 days of available buffer for process restructuring. And the system 2 with three days delay failed to support for process change on the full-fledge customization processes whereby its 3 days delay constraint in reacting to the problem exceeded the days of available buffer for process restructuring.

Following this, Fig. 11 demonstrates the percentage of processes the IIMA outperformed the other three systems across the three types of customization processes for both common supply chain deviations. In Fig. 11a which represent the outperform percentage by IIMA for support against transportation delay, the gap between system 1 and system 2 is quite large. For example, in the basic customization processes, the IIMA completed 80 percent more processes than system 1 but the IIMA is at par with system 2. As the number of processes increase, the IIMA began to outperform system 2 with five days delay and three days delay at approximately 40 and 20 percent respectively in the full-fledge customization processes.

However, the gap of outperformed percentage by IIMA between system 1 and system 2 are still large at approximately 50 percent with 5 days delay and 70 percent with 3 days delay. In contrast, Fig. 11b represent the outperform percentage by IIMA for support against misplace items and the gap between system 1 and system 2 are quite small compared to the when the problem occurred at the beginning of the customization processes phase. For example, in the basic customization processes, the IIMA execute more processes than system 1, system 2 with 3 days delay and system 2 with 5 days delay at 20 percent and 0 percent respectively; and the gap between system 1 and 2 is merely 20 percent. As the number of processes increase, the percentage of outperformed processes by IIMA dropped to approximately 11 percent for these systems in the full-fledge customization processes.

For this second case with the smallest outperform gap by the IIMA, the authors decided to use statistical approach in order to prove that the IIMA perform better than the other three systems. This is accomplish by creating a hypothesis and testing it using the data from the simulation in the full-fledge customization processes. Specifically, the authors had used only data from the system 2 with 3 days delay for testing the hypothesis. The reason for selecting this data is because the performance of system 2 with 3 days delay is the most promising compared to the other two systems. If there is significant difference between the number of completed processes with the support from the IIMA and system 2 with 3 days delay, the authors can infer that IIMA also perform better than the rest of the systems.

The Mann-Whitney U test is employ as the mean for analysis. The authors had chosen this test because it takes two independent non parametric samples to compute their significant value. Fig. 12 demonstrates the mean rank and test statistic for processes completion supported by IIMA and system 2 with 3 days delay using the Mann-Whitney U test. The value of 10.5 and 30.5 for the mean rank indicate that the distribution span for completed processes supported by IIMA and system 2 with 3days delay are very different from each other. In addition to this, the test statistic of less than 0.05 confirms that difference in the processes completion supported by the IIMA and system 2 with 3 days delay is significant.



	Basic	Focus	Full
Type1	400	600	800
IMA	0	0	0
Type2(3Days)	0	0	200
Type2(5Days)	0	200	400

Fig. 13. Percentage of Performance Degradation across Deviations

Fig. 13 demonstrates the performance of these support systems across the two types of problems in basic, focus and full-fledge customization processes. For system 1 and system

2, their performances are better when impinged with the problem at the ending phase of the customization processes rather than at the beginning. System 1 and system 2 drop approximately 400, 200 and 0 percent respectively in their performance during the focus customization processes. As the number of processes increase in the full-fledge customization processes, their performance drop even higher at approximately 800, 400 and 200 percent respectively whereby there are 200, 200 and 200 percent increase respectively from focus customization processes.

In contrast, the IIMA show a more stable performance compared to the other three systems. The IIMA did not experience any degradation in its performance across the two type deviations and provide consistence support regardless of the problems occurring at the ending or beginning phase of the customization processes.

VI. Discussions and Conclusions

The customization processes are shared processes between the members in the supply chain group to produce e-commerce solutions to the clients. The integration challenges limit the flexibility of the supply chain group to restructure their current shared processes to overcome common supply chain problems. The IIMA utilize the coordination algorithms to generate an intermediary processes which run silently on the background and provide support to the customization processes for more flexible processes. This support is important especially when the shared processes are impinged with problems that might cause the unmet demands and to incur additional costs to fix the problems later. The IIMA facilitate continuous monitoring of the current shared processes across the group and allow process restructuring by mixing the right services as the newly modified global shared processes.

These two abilities from the IIMA are imperative to the address the integration challenges and to provide support for more flexible supply chain processes. As demonstrated from the simulation, system 2 deterioriated in its performance as the number of processes it need to support increased. This is because the buffer available in days decreased as the number of processes increased and system 2 required the minimum of 3 days to react accordingly to the problems. This shows how important the first ability of the IIMA which are to faciliate continuous monitoring and detecting any deviation from the global shared processes.

In contrast, system 1 has the ability to provide continuous monitoring but had failed to react accordingly to the problems. As demonstrated from the simulation, the performance of system 1 deteriorated approximately 800 percent because the remaining processes stop from execution unless the problems are resolved on its own without any intervention from the group. The example for this is the problem with transportation delay, but by the time the transportation came to pick up the servers at the manufacturer loading bay, the time frame allocated for the customization processes has exceeded.

Conversely, the IIMA running on the coordination algorithms provide both of these abilities and proven to be stable in its performance throughout the occurance of the problems at the beginning and ending phase of the customization processes. The intermediary processes are accomplished by generating the mean of monitoring, detecting, consulting and restructuring as RFID services and integrated into the global shared processes. The authors believe that coordination algorithms can be adapted to support different supply chain domain by configuring the support models to the local context.

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