

Trust Based Agent Geographic Coalition Formation for Vehicular Networks

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Abstract— The primary objective of Intelligent Transportation Systems (ITS) is the creation of advanced road traffic safety systems for improved traffic safety, efficiency, and travelling comfort. These systems provide a reliable underlying communications infrastructure upon which a diverse range of user-orientated services can be developed and deployed. The application of agent technology to conventional networks and the services that run on them has significantly improved their capabilities specifically in the area of eCommerce. The development of these agent enriched services has revolutionized the eMarketplace, removing search monotony from the user while simultaneously increasing the purchasing power of the consumer. In recent years the potential of applying the theories of agency to the vehicular environment has been realized with infrastructural and traffic management systems being significantly augmented. In this work, using the more consumer orientated elements of agent applications and applying them to a vehicular scenario, we introduce the Commercial Vehicular Agent System (CVAS) for trust based transaction and service provision, a novel framework, architecture and implementation.

Index Terms—agency, vehicular networks, trust, coalition formation

I. INTRODUCTION

The advent of wireless networking has led to applied research in the intelligent transport domain. The possibility of collaboration among vehicles and roadside infrastructure brings a new dawn for transportation systems in which the goals of improved safety, traffic efficiency and environmental benefits can be addressed. The reality of vehicle and roadside infrastructure advances the aspirations and expectations of application developers providing them with a killer application space for MANETS (Mobile Ad Hoc Networks). It is hoped that developers can leverage this new infrastructure to provide value added service for its users. With this in mind, we assume a reliable underlying communications framework upon which services and applications can be deployed. The infrastructure that will be assumed is an incarnation of an ITS called Cooperative Vehicle-Infrastructure Systems (CVIS) [14]. This is a FP6 EU funded integrated project under the eSafety initiative whose goal is to create a cooperative vehicle infrastructure environment, empowering information exchange among vehicles and between vehicles and roadside infrastructure in an effort to seamlessly provide a number of intelligent transportation services. In this vision for a

cooperative vehicle infrastructure environment, CVIS proposes a heterogeneous cooperative communications framework based on the Continuous Air Interface for Long to Medium range (CALM) standard to provide user transparent, continuous communication in support of emerging ITS applications in the public transport, urban, interurban and freight and fleet domains. Much of the work being carried out in the ITS domain however focuses on the development of driver assisting services and the underlying communications technologies which fails to take full advantage of this new resource.

Prior to the widespread dissemination of the Internet, customers had to go physically from retailer to retailer in order to maximize their value for money. With the Internet came competition. No longer were customers restricted by geography and the online shopping industry was born. The market was seen a lucrative one by both businesses and customers alike, with both sides reducing the per unit cost of a transaction. Existing companies adapted by offering their goods and services as an online alternative, with other companies appearing as solely online entities. With a superfluity of options now available it became more tedious for customers to locate the services that met their criteria. In later years the theories of agency were developed and applied to this domain, massively augmenting not only the efficiency of the marketplace but also the buying power of the consumer. These agents automated the searching process, presenting the user with only those options that met their criteria. It also provided an environment where ad-hoc coalitions could be forged that worked to the advantage of all its members. The impact that the application of agency had on the eMarketplace cannot be underestimated. The application of software agents to the online retail industry has revolutionized the way we transact online and eCommerce as a whole.

A similar phenomenon is now occurring as vehicular networks proliferate. Both drivers and passengers signify a key potential market where software and hardware vendors can extend service areas beyond the desktop computer. In the Western world, drivers and passengers spend a significant part of their lives in cars. According to the Intelligent Transportation Society of America, there are more than 201 million cars in the United States with Americans alone spending in excess of 500 million hours in their cars each week [1]. The vehicular market represents an opportunity which cannot and is not being ignored by service providers. Taking advantage of this many vendors have adapted their sales strategies by offering existing services in a convenient “drive-thru” format. Food, banking and even prescription

drugs are now all available as drive-thru options, the popularity of which has exploded. According to a 2007 American National Restaurant Association report, sales at quick service drive thru's reached a staggering \$150 Billion [2]. We are on the verge of realizing a fully functional, reliable vehicular internetwork. A unique market is about to emerge. This new market has many similarities to the traditional electronic marketplace however it mandates some unique adaptations. The needs of consumers change when they transition from a traditional online market to this new vehicular marketplace, consequently the type of service available to the user will be different. In most scenarios the driver will not set out to explicitly avail of these ancillary services, but rather will avail of them as part of an overall larger journey. For example, drivers on their way home from work may wish to re-fuel their vehicle and purchase fast-food, both of which could be located and discounted by the framework proposed in this paper.

In order to capitalize on this emergent market, a structure must be put in place that facilitates and nurtures an electronic vehicular network marketplace where customers can take advantage of increased vendor competition. As stated earlier, much research has been undertaken to develop infrastructure and network oriented applications that have little direct commercial appeal. Few researchers address the potentially lucrative niche being created by this new technology and more importantly, how to innovate solutions and adapt existing paradigms to exploit it. The work presented in this paper focuses on providing a framework for service provision in a vehicular environment using agent technology, a concept that has been thus far unexplored

The remainder of the paper is organized as follows. The next section synthesizes related work in the area. The theories of agency as they relate to this endeavor and the motivation behind their utilization is outlined in section three. The proposed architectural solution and its envisaged operation is described in section four. Section five contains information on the concrete implementation of the system, with section six providing the conclusions and areas for future work.

II. RELATED WORKS

This paper describes a framework that harnesses the unique properties of agency (i.e. trust, coalition formation, etc) for use in a vehicular setting. These attributes of agency have been well explored in conventional environments, as exemplified by [3] which explores the formation of agent coalitions using trust and motivation as factors. For further reading in this area the user is referred to [4] [5]. A natural extension of this work was to use these agent traits in the electronic marketplace. Agents have been adapted to use auctioning mechanisms in addition to their ability to trust and form coalitions. In [6], Guttman et. al undertake comprehensive analysis of the use of agent technology in electronic commerce. More detail on other work in this area can be found in [7] [8]. These look more closely at the processes of adaptive brokering and long term coalitions in the marketplace, concepts which are highly relevant to the proposed framework.

As the work outlined here has been built with a vehicular ad-hoc network in mind, it is prudent to mention other works in the area of agents and mobile/vehicular environments. . In [9] Yin & Griss describe an agent based multimodal traveler information system which has the ambitious goal of fusing multiple data sources (e.g. weather reports, transit schedules) into context aware information to assist a user in a travel scenario. While this paper does incorporate agents in a mobile scenario, it is not aimed at an automobile network nor does it include any trust/coalition concepts mentioned earlier. As the area of ITS and vehicle networks is an emergent technology, work in this area is relatively limited, with most research being of a theoretical nature with little implementation. What work has been done concentrates on using the abilities of agents in the areas of traffic management and collaborative driving systems. In [10] work is presented that use agents resident on a vehicle to automate traffic movements at intersections. It is important to note that the agents collaborate, they do not form coalitions and have no knowledge of an electronic marketplace.

To surmise, there has been much work done researching the applications of agents to the eMarketplace and all that entails. More recently software agents have begun to play a role in ITS and vehicular networks however this role has thus far ignored the consumer orientated aspects of agency that made them so popular in conventional networks. It is the goal of this paper to take these attributes of agency and apply them to a vehicular environment and in the process provide a novel architecture and implementation.

III. SOFTWARE AGENTS

In today's modern world, computers are now as ubiquitous as cars or televisions. As this technology proliferates, the gap between the millions of untrained users and an equal number of sophisticated microprocessors will become even more apparent. Computers currently respond only to what interface designers call direct manipulation. Nothing happens unless a person gives commands from a keyboard, mouse or touch screen. The computer is merely a passive entity waiting to execute specific, highly detailed instructions; it provides little help for complex tasks or for carrying out actions that may consume a large proportion of the users time (e.g. searching for information). This is where software agents come in. They "know" users' interests and can act autonomously on their behalf. Instead of exercising complete control, people will be engaged in a cooperative process in which human and computer agents initiate communications, monitor events and perform tasks to meet users' goals.

As mentioned in section 1, the number and type of application domains in which agent technologies are being applied to or investigated are numerous. However despite the recent surge in interest in agency and its applications, investigations have yet to be carried out on the coupling of agents, trust and coalitions in a vehicular environment.

The concept of agent trust is a simple one. Agents in the electronic market place are broadly categorized into buyer and seller agents. The agent behaviour is designed in such a way as to allow these agents to 'remember' transactions they have had

with other agents. Initially there exists no positive or negative bias towards other agents, however as time goes by and interactions occur agents will begin to trust or distrust their peers. This change happens as a result of an evaluation carried out by each agent rating its experience with another as either positive or negative. The result of these appraisals is that an agent that had a positive encounter with another will be more likely to have future business with that agent and vice-versa. The concepts of agent trust and coalitions are very closely linked. The main reason for forming coalitions is to bring agents with compatible preferences closer, by nurturing vendor-customer relationships. This policy is motivated by the fact that establishing a friendly and trustworthy relationship with clients promises vendors more transactions in the long run and retention of customers known as customer relationship management [11].

The next level of abstraction in an agent based marketplace is negotiation. We now have groups of buyer agents that trust each other and have banded together in order to maximize their savings, both in the process of electing a coalition representative and in determining the optimal vendor negotiation tactics that are used. There are four common types of single side auction/negotiation, the explanation of which is outside the scope of this paper, the reader is referred to [12].

We have taken these concepts and applied them to a vehicular setting. A software agent will reside on each CVIS platform forming, joining or leaving coalitions using their trust in members of that coalition as the motivating factor. These coalitions then scan the marketplace for the vendor that best fulfils the coalition's needs. The coalition leader then interacts with this vendor and brokers the best deal it can for the agents it represents. We have used the size of the coalition and the trust placed in it by the vendor agent as contributing factors to the transaction with larger more trustworthy coalitions obtaining greater discounts on their goods/services than smaller less trusted ones.

IV. SYSTEM ARCHITECTURE

In order to successfully design and implement the framework proposed above, several requirements must first be considered. Primary among these requirements are the capabilities of the underlying network; vehicles need to communicate with their peers and with the infrastructure itself. Interruption in the communication process at the network level could lead to service disruption at upper levels, and therefore cannot be tolerated. In its mission statement CALM has stated that it will provide user transparent continuous reliable communication which can therefore accommodate the incorporation of application level agent technology. CALM itself is a standardized draft series of air interface protocols for ITS services and applications. These protocols are predicated on the principle of making best use of the resources available.

A second requirement is that for an agent augmented system to function it needs a platform from which the agents can operate. This platform will allow various types of agent running in different areas of the network to intelligibly communicate with one another. Finally, the determination of the vehicles position and the use of this information to determine what services will

be available is a key requirement of the framework. This positional information will also be used in the coalition formation process which will be outlined later.

Based on the three requirements detailed above figure 1 shows a generic architecture for the provision of location based services on a vehicular network integrating the agent paradigm. Each of the major components of the architecture are described in more detail in the following subsections.

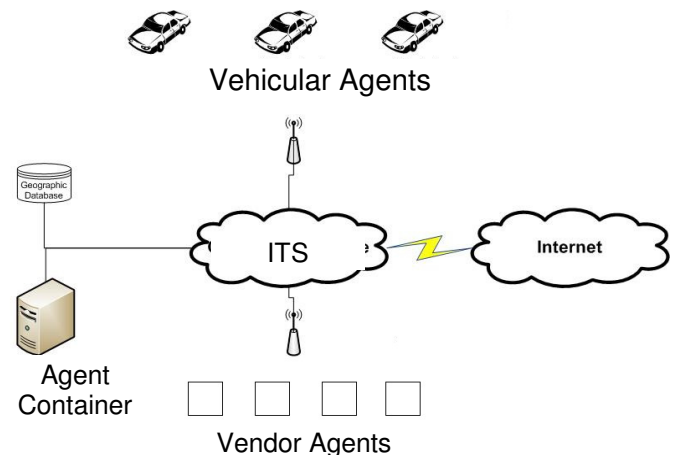


Figure 1 : Component Architecture

CVIS Infrastructure

To enable vehicles and infrastructure to talk and understand each other, CVIS uses mobile broadband technology, adapting it to make it possible for the vehicle and its occupants to stay online while on the move. Each vehicle in the network will be equipped with a CVIS platform which has four main components:

- Based on the world's first implementation of the emerging "CALM" standards for vehicle communications, the CVIS vehicle unit can provide continuous IPV6 connection using whichever is the best available channel or network (choosing from mobile 2G/3G cellular, wireless LAN, short-range microwave (DSRC) or infrared).
- The CVIS unit also includes a hybrid location module with GPS and innovative positioning techniques providing accuracy down to one meter. Another service will update and deliver to nearby users a "local dynamic map" with the real-time position of the vehicles in the vicinity, relative to the local roadside infrastructure. CVIS also guarantees the development of a common solution for location referencing in all types of CIVS applications.
- The third major component of the platform is a middleware layer with a runtime environment, core service modules such as security and authentication and Application Programming Interfaces (APIs) for vehicle, roadside equipment and driver interfaces. These are based on open standards, as openness is essential to ensuring that users can access CVIS services everywhere and that service providers can address all vehicles and users.

- Finally, the CVIS vehicle platform also includes a monitoring server, processing and delivering data collected from vehicle sensors, so called “floating vehicle data”. When data from vehicles and from roadside sensors are fused, this provides information about the immediate traffic conditions throughout the road network as well as warnings of traffic incidents and environmental hazards.

Agent Platform

The agent platform serves as a central area for locating and contacting mobile and detached agents. Services provided here include agent management, security, communication, naming and agent transport. The platform architecture is as follows:

- Agent Management System (AMS): controls creation, deletion, suspension, resumption, authentication, persistence and migration of agents. Provides a “white pages” directory to name and locate agents.
- Agent Communication Channel (ACC): routes messages between local and remote agents, realizing messages using an agent communication language (ACL).
- Directory Facilitator (DF): Provides a “Yellow Pages” service for agents that register agent capabilities so an appropriate task-specific agent to handle the task can be found.
- Internal Platform Message Transport: Provides a communication infrastructure.

Software agents

These agents fall into two main categories, namely the customer agent and the vendor agent. The former will run on the in-vehicle platform provided by CVIS with the latter having greater flexibility with the ability to run on multiple platforms in multiple environments. Essentially these agents are Java entities that express behaviour that is defined by the preferences of the user to which it belongs.

Geospatial database

As stated earlier, part of the CVIS project is the provision of a dynamic map which the users of the network can use to triangulate their position both globally and in relation to other vehicles in the locality. It is our intention to leverage this map to provide the agent augmented location based service, by segmenting the map in to different areas. These areas will determine the service boundaries and restrict agent interactions to predetermined regions. In essence we are overlaying a lattice onto the existing database which will allow the agents to become spatially aware.

V. IMPLEMENTATION

The previous section outlined a generic architecture for the provision of a service orientated vehicular network using agent technology. This framework can, in theory be used to enhance any transaction based service that is resident on the network. For the purposes of implementation, a specific scenario has been chosen which best illustrates the promise of the technology.

One of the strengths of service provision in the traditional online marketplace is that consumer location is not an issue. This is not the case in a vehicular environment. Failure to provide location based services drastically underutilizes the potential of this new resource. Depicted in figure 2 is our sample scenario where customer agents seek out other customer agents with similar needs prior to approaching a vendor agent with an ultimate goal of finding the lowest cost provider of petrol in their area. The first stage of this process involves a buyer agent searching its vicinity for other buyers that are also looking to purchase petrol. Once found each of the buyers concerned begin searching the region for a suitable vendor. Each of the buyers will contact vendor agents in the region requesting a price. The seller agents use their trust values in the approaching agents to calculate a discount. The buyer agent that provides the lowest estimated price becomes the coalition representative and is henceforth responsible for contacting the vendor agent, requesting a sale and ensuring that all agents concerned receive the promised discount.

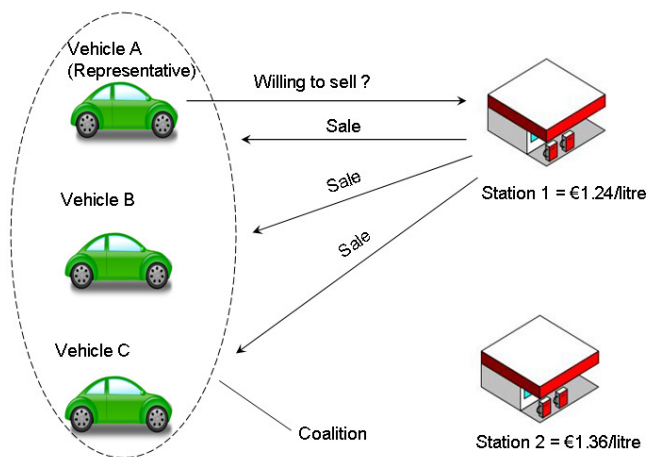


Figure 2 : System Overview

Depending on the magnitude of trust the vendor has with the coalition representative, a discount is applied. Such a policy is motivated by the fact that establishing a friendly and trustworthy relationship with clients promises vendors more transactions for the long run and has been proven to retain customers. In this case trust is used as a means of assessing the perceived risk in interactions; representing an estimate of how likely another agent is to fulfill its cooperative commitments. What follows is an outline of the system that has been implemented using the scenario outlined above, beginning with the Open Services Grid Infrastructure (OSGi)

OSGi

Among the unique requirements of the CVIS environment is that manufacturers must have the ability to remotely and dynamically upgrade automotive software quickly, economically and securely. Due to the diversity and lack of standardization when it comes to vehicle type and software of the automobiles populating the network, a service platform must be selected that can run on almost any operating system and processor.

The OSGi specification defines a standardized, component orientated computing environment for networked services that is the foundation of an enhanced service orientated architecture. The addition of this service platform adds the capability to manage the lifecycle of software components in the vehicle from anywhere in the network, while simultaneously reducing the overall complexity of building, maintaining and deploying applications. Components can be installed, updated or removed on the fly without ever having to disrupt the operation of the device. The service platform itself has two components, namely the OSGi framework and a set of standard service definitions. The OSGi framework which sits on top of a JVM (Java Virtual Machine) is the execution environment for services [13].

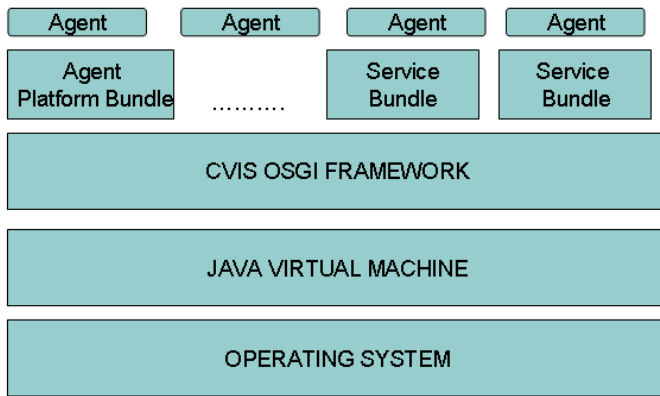


Figure 3 : Agent Orientated OSGi Framework

In OSGi, service providers and requestors are part of an entity called a bundle that is both a logical as well as a physical entity. Service interfaces are implemented by objects created by the bundle. In standard OSGi, the bundle is responsible for run-time service dependency management activities which include publication, discovery and binding as well as adapting to the changes resulting from dynamic availability of services that are bound to that bundle.[14] The overall structure for of the framework is shown in figure 3 above, with the agent orientated elements of the system bundled and presented as separate OSGi services within the platform. The main agent platform has been adapted to run in this new environment with the vendor and consumer agents being loaded into the OSGi framework dynamically as bundles.

GEOSPATIAL DATABASE

Each agent in this system is aware of its location which will determine the other agents it interacts with and the services it can avail of. In order to realistically represent this spatial awareness in the agents we have overlaid a grid onto an accurate topological map of the Cork region in Ireland. This aids in our goal of location based coalition formation and service delivery by partitioning the map into regions. The construction of a zone on the map involves the calculation of four co-ordinates, with each of these points then linked to form a square. This process is then repeated for each region producing a grid as can be seen in figure 4. This regional segregation is achieved with the use of a PostGIS database

server, to which each agent has access and the ability to form and interpret SQL queries. The use of the map in the implementation serves as a temporary substitute for the CVIS maps which are still in the developmental phase.

When necessary the agent will firstly contact the appropriate CVIS OSGi bundle which will supply the agent with its co-ordinates. The agent will provide these co-ordinates to the database which can then determine the region in which the agent is currently residing. The areas in the database are represented by integer numbers which greatly simplifies the process as, for the purposes of this scenario, it is not necessary for the agent to possess positional information beyond its general area.

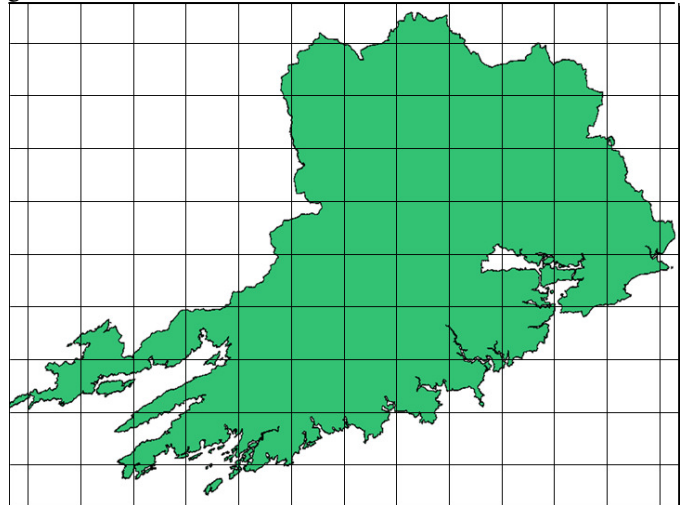


Figure 4 : Geospatial Database with Grid Overlay

Each of the regions is represented on the agent platform by a container. These containers are highly dynamic allowing them to be populated by many agents for both extended and fleeting periods of time. This property lends itself perfectly to the vehicular environment and the proposed scenario. A buyer agent running on a vehicle can join and leave containers as it moves from area to area, with this transition being entirely transparent to the end user. In figure 5, a more detailed look at the operation of the regional divisions is presented. Each area is populated with static vendor agents and mobile consumer agents. As these consumer agents traverse the map they interrogate the agent registry for other agents that are looking to engage in a transaction. The agent registry puts these likeminded agents in contact with each other leading to the formation of a coalition.

TRUST

The notion of trust is essentially a means of assessing the perceived risk in interaction; trust represents an agent’s estimate of how likely another agent is to fulfill its co-operative commitments. [3]. There is another dimension to trust that is being incorporated into this scenario, namely loyalty. Agents both vendor and customer alike both react to successful transactions, altering their trust relationship with the associated agent in order to bias itself toward that agent in the

future. We are taking this concept a step further and introducing a trust based discount to loyal customers.

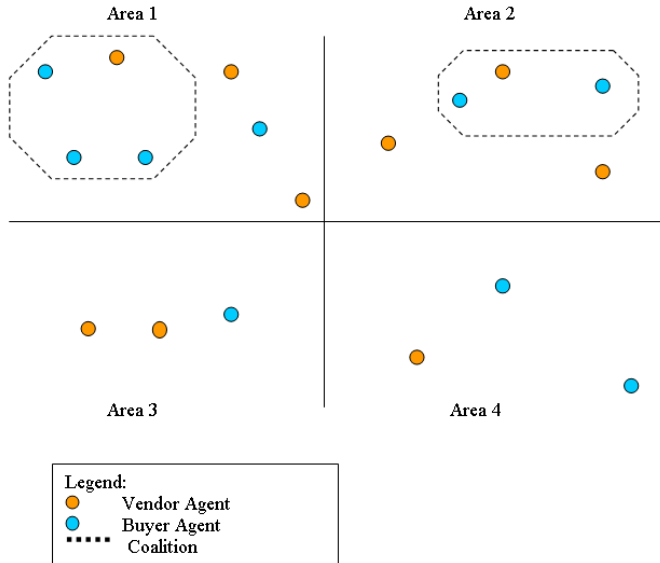


Figure 5 : Regional Coalition Formation

The greater the trust an vendor agent has in its customer, the greater the discount that customer will receive, consequently it is in the best interests of all concerned to nurture relationships that will provide positive trust and avoid potential negative ones. To achieve the basic mechanism of trust we based our model upon Marsh’s formalism [15] and define the trust in an agent to be a value in the interval between 0 and 1. Values approaching 0 represent complete distrust while those approaching 1 absolute faith. Each agent has an initial default trust value with all agents it encounters in the network, which then gets altered based on its experience. It is this value that the agent will use to determine whether or not to join a coalition or conversely whether to leave a current coalition and attempt to form another. Once an agent has decided to join a coalition this trust value is again used by the agent as a factor in its estimation of how much the vendor agent will untimely discount the service based on previous experience. The agent in the coalition with the lowest estimated price will become the collectives representative in negotiations with the vendor agent. In the final stage of the transaction the vendor will use its trust in the coalitions’ representative to calculate the discount and apply it to all its members. This discount is calculated using the following formula:

$$\text{finalPrice} = \text{price} - (\text{price} * (\text{trustValue} / 100))$$

This formula provides an accurate, if simplistic method of ensuring that greater trust values elicit a higher discount. Future incarnations of the system will incorporate a more complex and intricate formula for the calculation of trust. For example we plan to introduce an additional incentive to buyers willing to purchase larger volumes of fuel. Once the transaction has been completed each member of the coalition will perform an evaluation of its experience updating its trust in the agents involved.

JADE

The need for development environment tools to aid designers in the specification and design of agent based systems is crucial. Agent development tools ease the integration of agents into existing environments by supporting the unique requirements of interface agents (e.g. the need for user modeling) and ensuring compliance with existing practices and user interface standards [16].

The JADE framework was selected as the agent platform for this endeavor for many reasons, primary amongst them being that it can be adapted to integrate with the OSGi framework, presenting registered agents as OSGi bundles. While appearing as a single entity to the outside world, a JADE agent platform itself is a distributed system, since it can be split over several hosts with one of them acting as a front end where the AMS (Agent Management System) and DF (Directory Facilitator) are placed. A JADE system, as shown in figure 6 comprises of one or more agent containers, each living in a separate JAVA virtual machine and delivering some runtime environment support to some JADE agents. JADE distinguishes between inter-platform messaging and intra-platform messaging. Inter-platform communication must be FIPA (Foundation for Intelligent Physical Agents) compliant; however inter-platform communication has no such restrictions, allowing for a less formal protocol. This ability makes it an ideal fit for the vehicular environment as the platform can be distributed at multiple locations throughout the infrastructure with a remote container representing each segmented geographic area. It also means that the inter-platform messages can be tailored to the needs of the environment. For example, the inter-platform messages transmitted in this scenario have been altered to include information on the agents zone within the map.

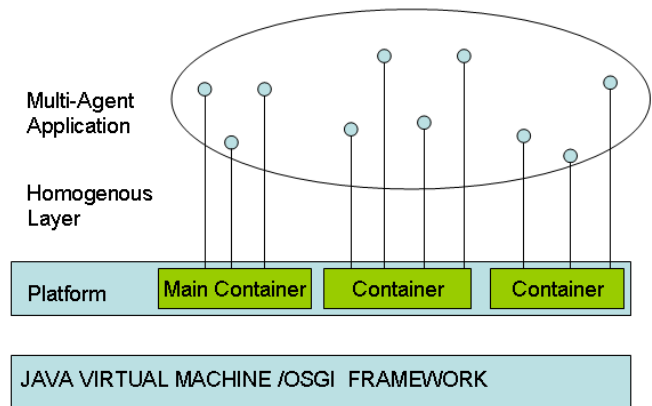


Figure 6 : The JADE Architectural Model

Finally, JADE has been adapted to be compliant with the FIPA Agent Communication Language (ACL). As mentioned earlier this means that internal platform messages have a pre-determined structure and semantics. While this restriction does not apply to inter-platform messages we have chosen to conform to the majority of these standards.

FIPA ACL (Agent Communication Language)

Agents need an agent communication language in order to interact in a shared language, hiding the details of their internals and to build communities of agents that can tackle problems that no individual agent can. When using ACL's agents transport messages over the network using a lower level protocol (in the case of the CVIS infrastructure this will be IPv6). The ACL itself defines the type of messages (and their meanings) that agents may exchange. Agents though, do not just engage in single message exchanges, they have conversations (i.e. task orientated, shared sequences of messages that they follow). At the same time some higher level conceptualization of the agent's strategies and behaviours drives the agent's communicative behaviour.[17]

The FIPA ACL is based on speech act theory: Messages are action, or communicative acts, as they are intended to perform some action by virtue of being sent. The specification consists of a set of message types and the description of their pragmatics, that is, the effects on the mental attitudes of the sender and receiver agents. Every communicative act is described with both a narrative form and a formal semantic based on modal logic. The specification also provides the normative description of a set of high-level interaction protocols, including requesting an action, contact net and several kinds of actions.

These software agents residing on the system have been designed to both generate FIPA ACL messages and react to them accordingly. A sample ACL message implemented in the system is shown in figure 7 below.

```
((action
  (agent-identifier
    name df@157.190.198.6:1099/JADE
    :addresses
      (sequence http://ee-b253-198006.elec-
        eng.local:7778/acc http://goc_postgrad:7778/acc
        http://goc_postgrad:1230/acc
        http://goc_postgrad:1235/acc))
    (search
      (df-agent-description :services
        (set
          (service-description
            :type fuel-buyer
            :properties
              (set
                (property
                  :name "Section Number"
                  :value 1))))
          (search-constraints
            :max-results -1))))))
```

Figure 7 : Sample Agent Message

This sample message is sent from a buyer agent in the initial stages of its activation as part of a larger conversation where it searches for other buyer agents in its geographic area with which to form a coalition. There are two environment specific adaptations of note in this message, namely the service description type and the property name. These extra components make the agent spatially aware in that each agent can only conduct a transaction in the area in which it currently

resides. This message can be seen in its context in the sequence diagram in figure 8. This is a simplified representation of the messages that pass between agents on the network as one of the buyers attempts to avail of the service offered by the Seller Agent.

When a registered buyer agent wishes to engage in a transaction it contacts the JADE Platform and requests all of the seller agents in its area. The agent is now aware of every available vendor and thus has a frame of reference. It then repeats the search requesting all of the buyer agents in the region that are available to form a coalition. Each of these agents is then asked for its best trust-adjusted price (this is an estimation based on an offer it will have gotten from seller agents in the vicinity).

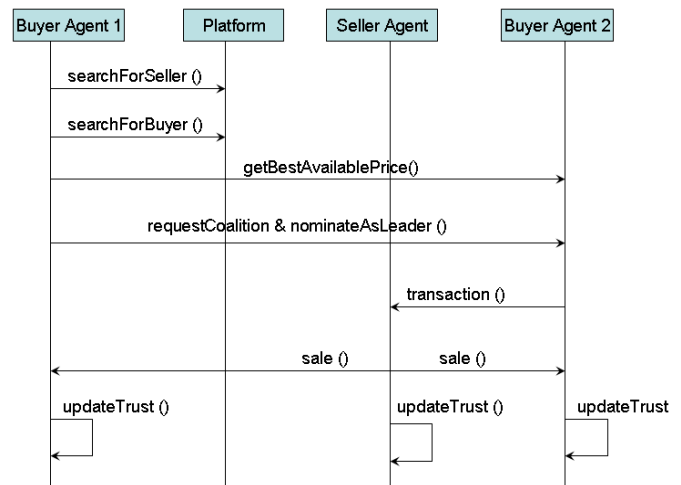


Figure 8 : Agent Messaging Sequence

All willing agents are incorporated into a small collective with the agent offering the lowest trust-adjusted price becoming its representative. It then becomes the responsibility of that agent to contact the vendor and conduct the sale on behalf of all members of the coalition. At the end of the transaction, each participant evaluates the experience (be it positive or negative) and adjusts their trust values accordingly.

VI. CONCLUSION & FUTURE WORK

This paper proposed a framework for a Commercial Vehicular Agent System allowing users in a vehicular environment to avail of location aware trust based services. We proposed a scenario for the purchase of fuel where buyers could, based on their region, form a coalition and avail a discounted rate based on trust. At present a rudimentary framework is in place where buyer agents can, based on their geo-referenced position, contact other buyer agents, form a coalition and elicit a collective and trust based discount from a seller agent.

In terms of future work there are three main areas that are of interest:

Trust – At present there is a very simplistic mechanism in place to calculate both trust and the trust adjusted discount. The agents will either increment or decrement their trust in another agent by one point depending on the success of the

transaction and as outlined earlier the method for calculating the discount is quite rudimentary. What will be introduced is a tiered trust calculation mechanism whereby trust values are determined based on multiple factors such as coalition size, volume of purchase etc. These enhancements will make the framework as a whole more realistic

Scalability –The system that is currently in place is populated with a small number of agents that were used solely as tools for testing the environment and developing more complex agent behaviour. The CVIS project has an end goal of deploying a large scale vehicular network. With both of these factors in mind, we intend to begin scaling the system and thereafter conduct a performance evaluation.

Region Size - The system is linked to a geospatial database that, for the purposes of simplifying the development process, has a grid of uniform areas imposed upon it. At present the areas take no consideration of locations with dense populations, high volumes of traffic, or indeed the number of vendors. With further development these segments will be altered to accurately reflect these factors. This will have the effect of increasing the efficiency of the transactions and limit the volume of inter-agent communications.

VII. ACKNOWLEDGEMENTS

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