Department of Electrical and Computer Engineering

SENG 609.22 – Agent Based Software Engineering

Course Instructor: Dr. Behrouz H. Far

(Fall 2002)

Tutorial Report

Agent Communication Languages and Protocols

By

Kalaivani Subramaniam

Table of Contents

Agent Communication Languages and Protocols

Kalaivani Subramaniam

Abstract

This paper provides an overview of Agent Communication Languages and Protocols. At present there are two such languages like Knowledge Query Manipulation Language (KQML) and Foundations for Intelligent and Physical Agents (FIPA) Agent Communication Language (ACL). Both languages are developed based on speech acts. KQML is the most widely used language. A basic idea of each language and protocols associated with them is discussed in this paper. FIPA ACL is the first attempt to standardize agents. Both languages are compared enlisting similarities and differences. Also the drawbacks of each language are discussed.

Keywords

ACL, Agent Communication Language, KQML, Knowledge Query and Manipulation Language, FIPA ACL, Foundations for Intelligent and Physical Agents, Speech Act, Performatives, Facilitator

1. Introduction

A software system is said to be an *agent system* if it possesses the following characteristics like **Knowledgeability, Learning, Autonomy and Communication**. An intelligent agent should be able to communicate with other agents using a communication language. The three basic problems associated with communication are *Interaction protocol, Communication language and Transport protocol*. In *Interaction protocol*, an agent is able to control its interaction with other agents. Interaction protocol ranges from negotiation schemes where each agent chooses its best option without considering the outside environment. So protocols should be designed based on noncooperative strategic perspective. *Communication language* is the medium for communication. *Transport protocols* include TCP, SMTP, http, etc.

A common language that shares common syntax, semantics, pragmatics and mutual understanding is required among the agents. Agent Communication languages differs from other methodologies through objects of discourse, semantic complexity and their ability to exchange more complex objects.

2. Evolution of ACL

Agent communication is one of the essential things in multiagent systems. According to **(Austin 1962; Searle 1969)**, *Speech Act* is a language adopted to analyze speech events and it is based on the fact that conveying information is not restricted to words. Based on

this theory, artificial languages have been developed that support interagent communication.

Advanced Research Projects Agency (ARPA) Knowledge Sharing Effort (KSE) focuses on developing techniques and methodology for knowledge sharing and reusing the knowledge **(5)**. The main idea is that knowledge sharing requires communication. A language of one agent should be understood by other agent whose native languages are different, or in other words agents should have a common language. To achieve common language, common syntax is necessary. Also, language should support common semantics which means concepts or entities should have same meaning among different applications. Communication is an important part of common language where agents communicate the complex attitude of their knowledge content.

Agent requests services from other agents, informs other agents and finds agents that can assist them. All of the above is possible through **Agent Communication Language (ACL).**

KSE proposed **Knowledge Interchange Format (KIF)** which is a language for handling syntactic aspects for knowledge sharing. KIF is used as a mediator in the translation of other languages i.e., translation is from language A to KIF and from KIF to language B.

3. Requirements of ACL

The various requirements in constructing ACL **(1)** are shown in Fig 1:

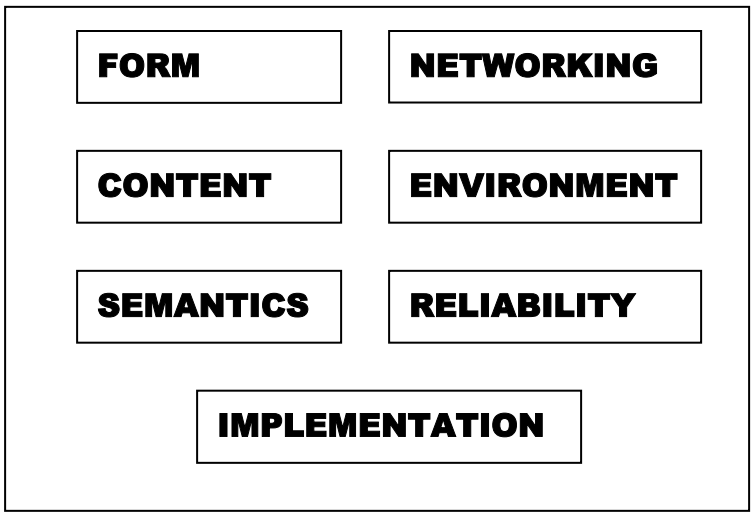

Fig 1. Requirements of ACL

i. Form

A good agent communication language should be declarative, syntactically simple, readable, concise, easy to parse and linear. Also the syntax should be extensible.

ii. Content

ACL should be layered into communication language that expresses communicative acts and content language that expresses facts about the domain.

iii. Semantics

Semantics of ACL include natural language descriptions and it should provide a model for communication. It requires a shared understanding of the language and protocols.

iv. Implementation

The implementation should consider speed and bandwidth utilization. It should have easy-to-use interface and fit well with existing software technologies.

v. Networking

The language should work well with existing networking technologies. It should also support point-to-point, multicast, and broadcast, synchronous and asynchronous connections. The protocols should be independent of existing transport mechanisms.

vi. Environment

The Environment should be highly distributed, heterogeneous and dynamic. It should be interoperable with other languages and protocols.

vii. Reliability

ACL should support reliable and secure communication among agents. The language should also identify and signal errors or warnings.

At present, there are two choices of Agent Communication Languages; they are *Knowledge Query and Manipulation Language (KQML) and Foundation for Intelligent and Physical Agent (FIPA) ACL.*

4. Knowledge Query and Manipulation Language (KQML)

4.1 Definition

"KQML is a language and a set of protocols that support computer programs in identifying, connecting with and exchanging information with other programs" **(2)**

KQML is independent of transport mechanism, content language and its ontology.

4.2 Layers in KQML

There are three layers **(4)** in KQML (see Fig 2.)

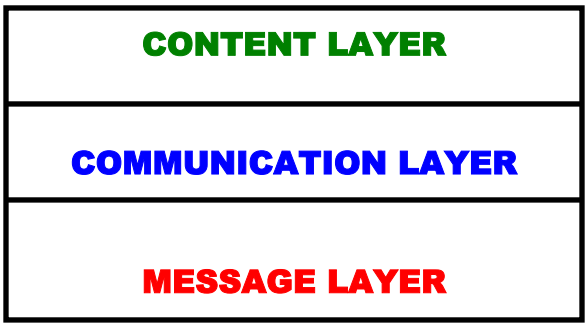

Fig 2. Layers in KQML

Content Layer

The content layer has the actual content of the message in the program's own representation language. KQML can handle representation languages in any of the format like ASCII strings. It ignores the content and uses them to determine the end of the message.

Communication Layer

Communication layer encodes lower level communication parameters like identity of the sender and recipient and unique identifier of the communication.

Message Layer

This layer is the heart of KQML. It encodes message, finds possible interactions with KQML speaking agent, identifies network protocol and supplies performatives. It also includes optional features like ontology, description of the content language, etc.

4.3 Performatives

A KQML message is called **performative**. Though the performatives are predefined, it can be extended. The parameters of performatives include keywords and values. Some of the performatives are ask-all, ask-one, tell, stream-all, standby, subscribe, etc.
Example: **(5)**

```
(ask-one
    : sender joe
    : content  (PRICE IBM ?price)
    : receiver stock-server
    : reply-with ibm-stock
    : language LPROLOG
    : ontology NYSE-TICKS)
```

4.4 Facilitator

KQML has special class of agents called **Facilitators**. "*Facilitator is an agent that performs various communication services like maintaining a registry of service names, forwarding messages to named services, routing messages based on content, providing matchmaking between information providers and clients, and providing mediation and translation services".* **(4)**

The semantics of KQML are preconditions, postconditions and completion conditions for each performative.

4.5 Communication Protocols

Protocol 1

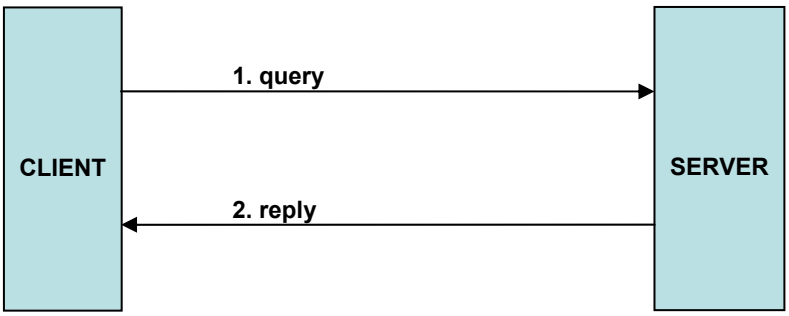

Fig 3. Protocol 1

Client sends query to Server and Server sends the reply. The Client has to wait for some time to get the reply.

Protocol 2

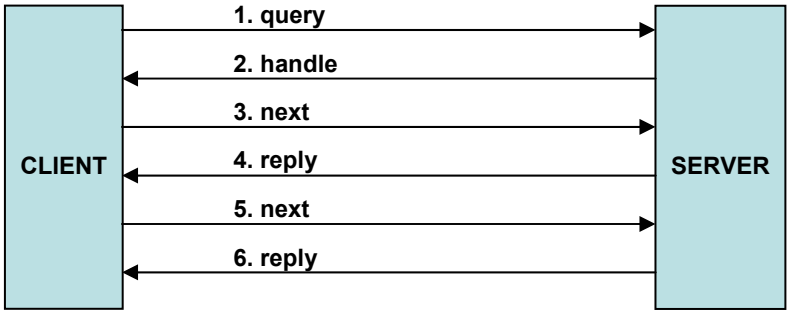

Fig 4. Protocol 2

Client sends query to Server. Server returns a handle. Client asks for reply one at a time and Server sends them.

Protocol 3

Fig 5. Protocol 3

Client subscribes to Server's output. Server sends indefinite number of asynchronous replies at irregular intervals.

5. Foundation for Intelligent Physical Agents (FIPA) ACL

5.1 Definition

"The Foundation of Intelligent Physical Agents (FIPA) is an international organization that is dedicated to promoting the industry of intelligent agents by openly developing specifications supporting interoperability among agents and agent-based applications" **(3)**

"FIPA Agent Communication Language is based on speech act theory where messages are communicative acts or actions" **(3)**

FIPA ACL specification consists of *message types and pragmatics*. A message is called performative. The outer language which defines the meaning of the message is separated from the content language. They follow different content languages. Here communication primitives are called *communicative acts*.

Semantic Language (SL) is defined as the formal language that represents FIPA ACL's semantics. The semantics of FIPA ACL are *feasibility preconditions and rational effect*. *Feasibility preconditions* are the essential conditions for the sender of each communicative act. *Rational effect* is the resultant effect that an agent may experience at the end of action.

5.2 FIPA ACL Message Structure

FIPA ACL messages are standardized to ensure interoperability and to provide well-defined process.

FIPA ACL messages contain various parameters based on the situations. Some of them are performative, sender, receiver and content. Among these, performative parameter should be compulsorily present. User defined message parameters are also allowed.

The various terms like *Frame* (represents each name of the class), *Ontology, Parameter, Description* (natural language description of the semantics of each parameter), *Reserved Values* (FIPA-defined constants) of each parameter defines the FIPA ACL message structure. **(7)**

Other parameters involved in ACL Message Structure are reply-to, reply-with, reply-by, in-reply-to, language, encoding, ontology, protocol and conversation-id.

5.3 Interaction Protocols

5.3.1 FIPA Request Interaction Protocol

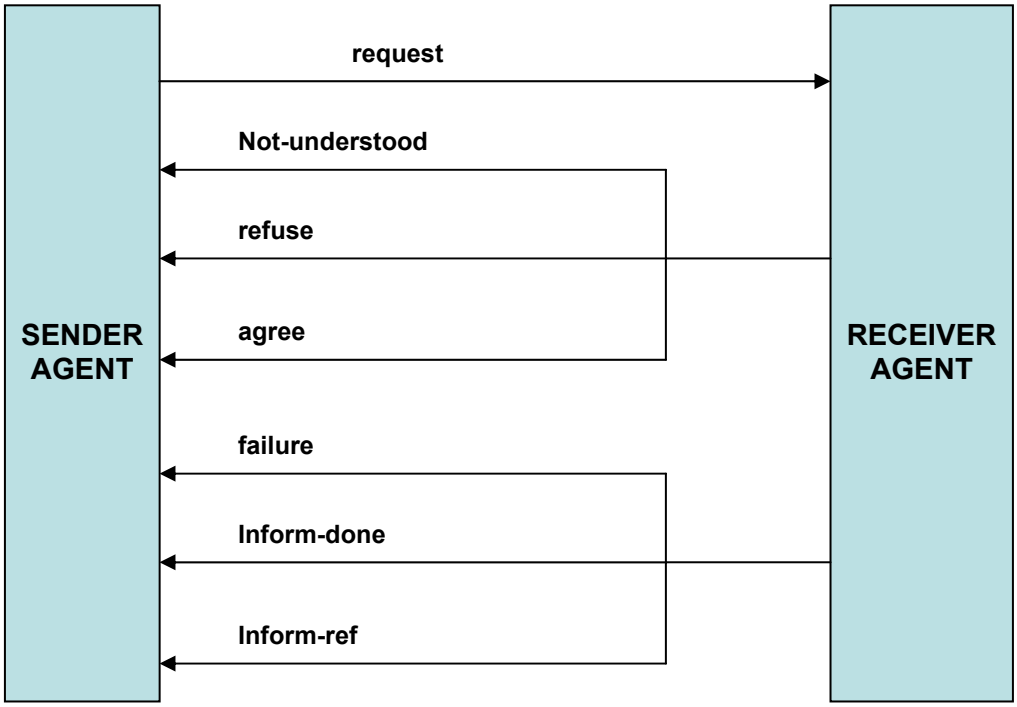

Fig 6. FIPA Request Interaction Protocol

Sender Agent requests an action from *Receiver agent*. The agent either fulfils the request or replies that it cannot do the task or refuses an action. Fig. 6 shows the FIPA Request Interaction Protocol. **(3)**

5.3.2 FIPA Query Interaction Protocol

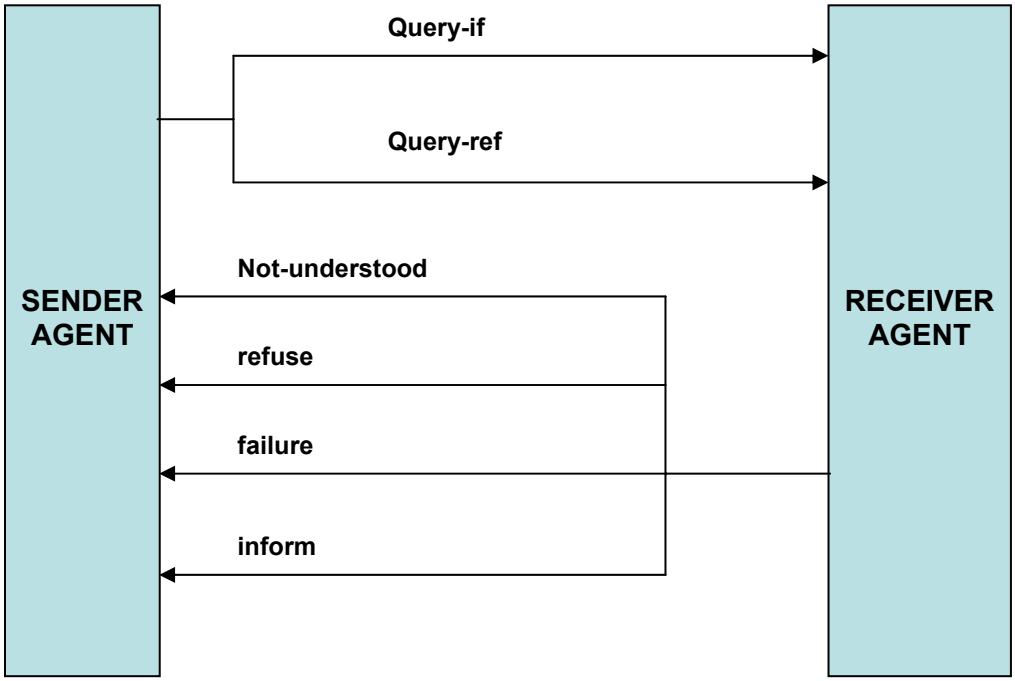

Fig 7. FIPA Query Interaction Protocol

Sender agent asks Receiver agent to perform *'inform'* performative that is an answer to the query. *Query-if and Query-ref* are two types of query acts. Inform is the response. In query-ref, response is the referring expression. Agent may also refuse the request or inform the failure. Fig 7 shows the FIPA Query Interaction protocol. **(3)**

5.3.3 FIPA Request When Protocol

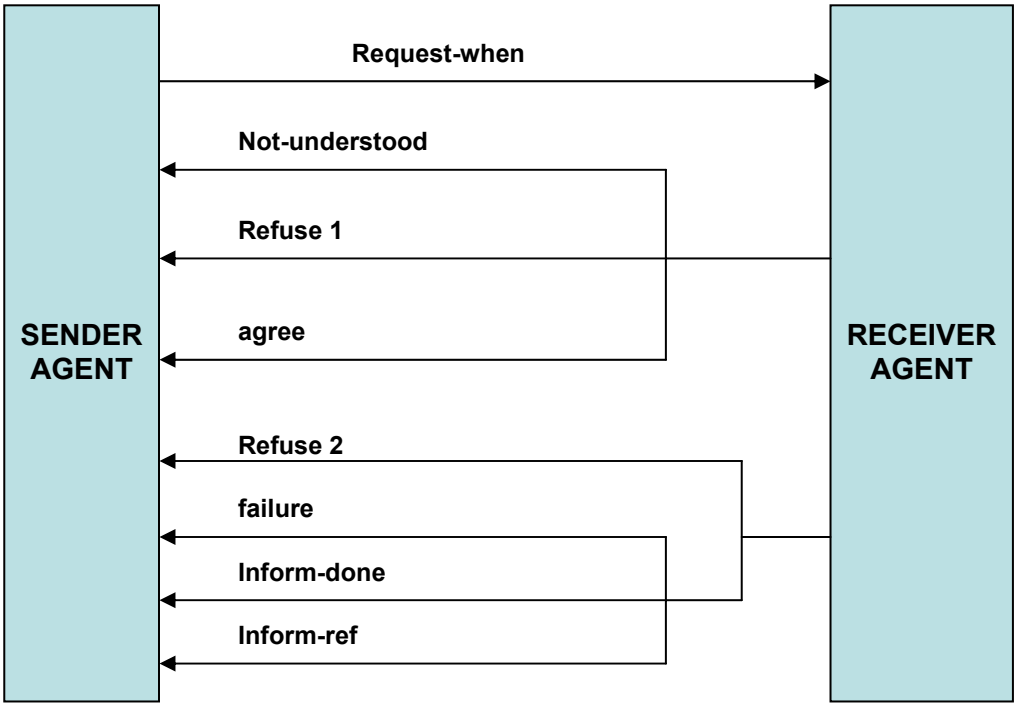

Fig 8. FIPA Request When Protocol

The Sender Agent requests Receiver Agent to perform an action, once precondition is true. At this stage, agent may refuse or accept it. At the end of precondition execution, agent may refuse or perform the action. **(3)**

5.3.4 FIPA Contract Net Interaction Protocol

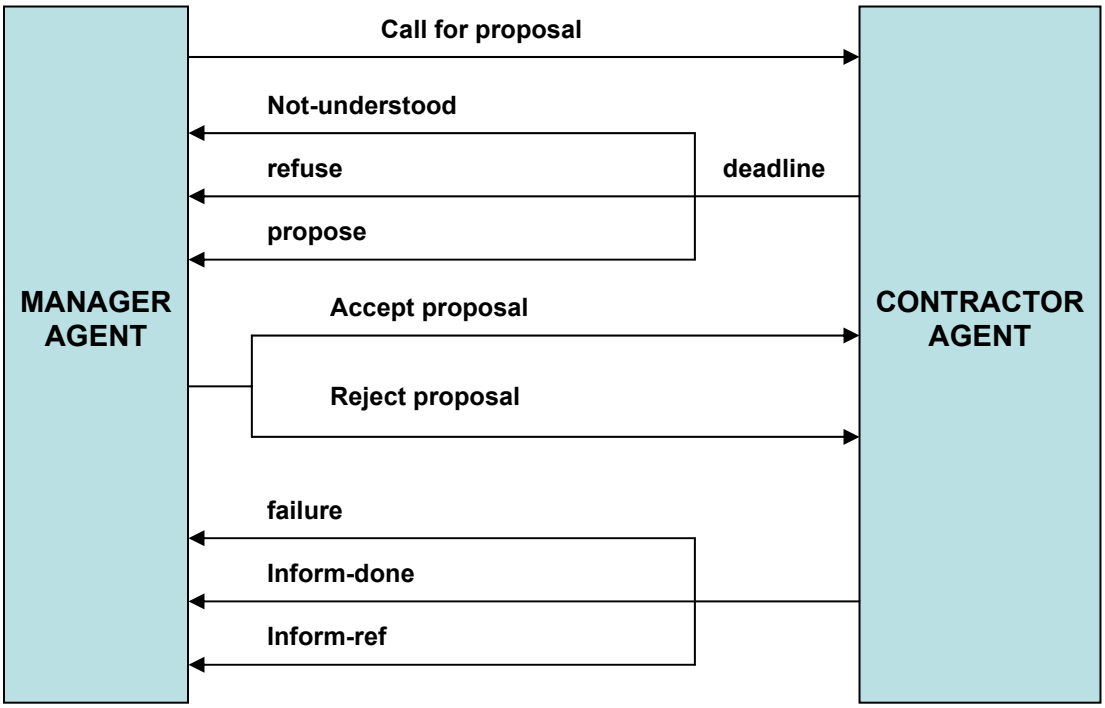

Fig 9. FIPA Contract Net Interaction Protocol

Contract-Net-Protocol was originally developed by *Smith and Davies*. *FIPA Contract Net Interaction Protocol* adds rejection and confirmation communicative acts to the previous version. In this protocol, one agent acts as *manager* that wishes to perform the task efficiently. By efficient, we mean either price or time-to-completion. It issues *call for proposals act* to other agents which are potential contractors. They prepare proposals and send them as propose acts. *Contractor agent* may also refuse to the manager agent. Once the deadline is over, the manager agent evaluates the proposal and send the accept proposal to selected contractor agent. The remaining agents receive reject proposal act. Contractor agent completes the task and sends the message to manager agent. **(3)**

5.3.5 FIPA-Iterated-Contract-Net Protocol

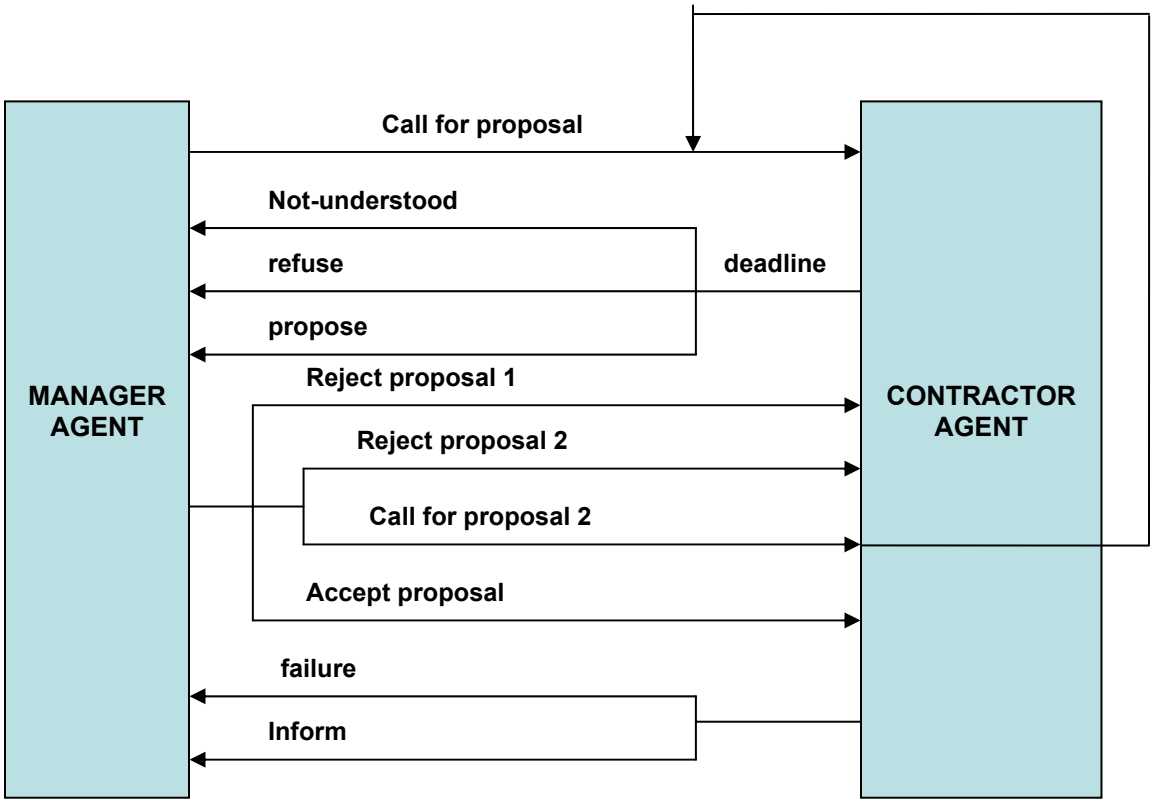

Fig 10. FIPA-Iterated-Contract-Net Protocol

This protocol is an extension of FIPA Contract Net Interaction Protocol. It allows multi-round iterative bidding. Manager agent issues call for propose acts and Contractor agents respond with propose acts. Then the manager agent may *repeat the steps* by issuing revised call for propose act. **(3)**

5.3.6 FIPA Auction English Protocol

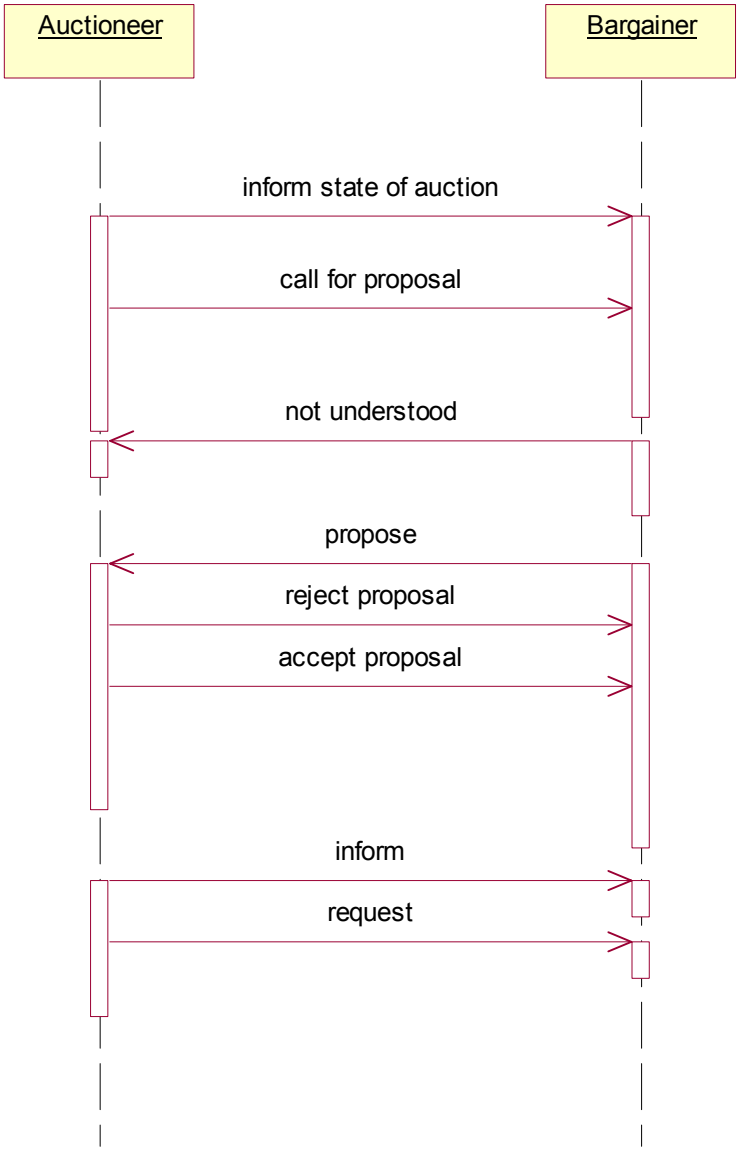

Fig. 11 FIPA Auction English Protocol

One agent acts as *auctioneer* and the other agents act as *bargainers*. Auctioneer calls for bids by sending a propose message to all bargainers. In this case, the initial price is low and it increases until client agent expresses its desire to buy. **(3)**

5.3.7 FIPA Auction Dutch Protocol

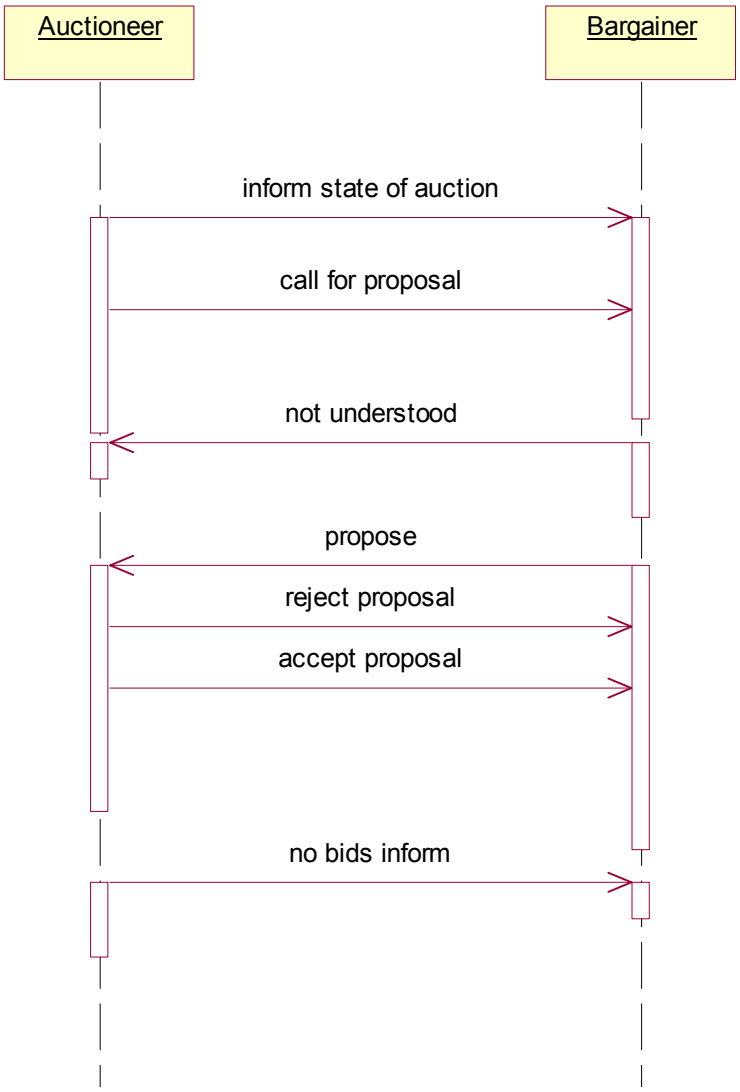

Fig. 12 FIPA Auction Dutch Protocol

This protocol is similar to *FIPA Auction English Protocol* except that the initial price is higher than the market price. The price is lowered until client agent accepts to buy. **(3)**

6. Comparison of KQML & FIPA ACL

Similarities (1)

1. Both are identical in concepts and principles
2. Both support different content languages
3. Both are syntactically identical
4. Both are capable of parsing messages, compose and channel them using low-level network protocol
5. Both are based on speech-act theory

Differences (1)

KQML	FIPA ACL
Semantic description includes preconditions, postconditions and completion conditions	Semantic description includes feasibility preconditions and rational effect
KQML has facilities for agent management and communication agent	FIPA ACL considers these as services offered by basic agents rather than message layer
KQML has facilities for multiple solutions like ask-all, stream-all, etc and goal definition like achieve and unachieve	FIPA ACL does not express these concepts in ACL, but in the context of ACL messages
KQML has facility for direct belief manipulation	FIPA ACL does not have this facility
KQML uses 'sorry' for both failure and refusal	FIPA ACL has facilities like 'failure' and 'refuse'.

7. KQML Critical Analysis

In KQML, the specification of services is incomplete. They are not clearly described in terms of functionality. The rational of elements in the language is unclear. Also there are no strict rules to identify communication primitives.

8. FIPA ACL Critical Analysis

The functionalities of content language is not clearly stated, this may be drawback to FIPA ACL. It does not have sufficient coordination primitives. The current trend shows that Internet Inter ORB Protocol (IIOP) is chosen as mandatory transport protocol, but transport model should be mandated.

9. Conclusion

Communication is the important characteristics of multiagent systems. KQML and FIPA ACL are two such languages in existence. This paper has presented some of the basic concepts in agent communication languages like KQML and FIPA ACL. The protocols and message structure of both languages is discussed.

We expect that the list of services should be expanded and also strict rules should be formulated to identify communication primitives. The transport model of FIPA ACL should be mandated.

KQML and FIPA ACL have both advantages and disadvantages. The choice of the language purely depends on the domain. However these issues will be a focal point of future work. Above all, these are the steps towards a fully automated agent-to-agent interaction.

10. Acknowledgements

The concepts and ideas in this paper are taken from FIPA specifications.

11. References

1. *Agent Communication Languages*
   http://www.ida.liu.se/labs/iislab/courses/Agents/paper/chapter3.html
   http://www.engr.uconn.edu/~ibrahim/publications/acl.htm

2. *UMBC KQML Web*
   http://www.csee.umbc.edu/kqml/

3. *FIPA Interaction Protocol Specification*
   http://www.fipa.org/repository/ips.html

4. *KQML as an Agent Communication Language,* Tim Finin and Richard Fritzson, Don Mckay and Robin McEntire
   http://www.cs.umbc.edu/kqml/papers/kqmlacl.pdf

5. *Agent Communication and Knowledge Sharing,* Behrouz Homayoun Far, University of Calgary.
   http://www.enel.ucalgary.ca/People/far/Lectures/SENG609-22/04/SENG609-22-04_files/frame.html

6. *Agent Communication Languages: Rethinking the Principles,* Munindar P. Singh, North Carolina State University.
   http://www.csc.ncsu.edu/faculty/mpsingh/papers/mas/computer-acl-98.pdf

7. *FIPA ACL Message Structure*
   http://www.fipa.org/specs/fipa00061/XC00061E.html