Coordination Protocols

FIPA Protocol Documentation

Overview

- Commitments & conventions
  - Simple protocols
- Cooperation protocols
  - Contract net
  - Negotiation
  - Market mechanisms
- Middle agent protocols
  - Brokering
  - Recruiting
  - Subscribe

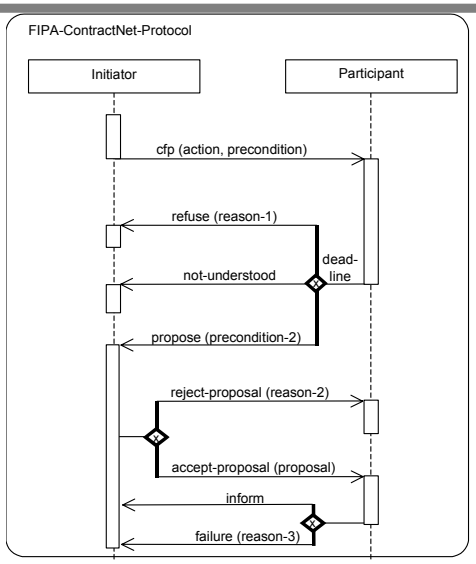
Protocols

- Ongoing conversations between agents often fall into typical patterns called protocols
- A designer could enable agents to reason about message meanings, etc.
  - Difficult
  - Computationally expensive
- A pragmatic solution is pre-defined protocols

AUML Protocol Notation

- Semantics
  - A protocol description represents an interaction – a set of messages exchanged among different agent roles within a collaboration to effect a desired behavior of other roles or agent instances.
- Notation
  - Vertical dimension represents time,
    - Time proceeds down the page
    - Only time sequences are important
  - Horizontal dimension represents different agent roles
    - No significance to the horizontal ordering of the roles
- Various labels can be shown either in the margin or near the lifelines or messages that they label
  - E.g., timing marks, generated goals depending on the received message, etc.

Notation



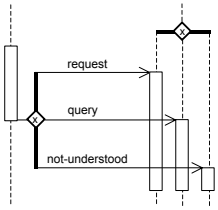
Role Lifetimes

- The lifeline may split into two or more lifelines to show AND/OR parallelism and decisions
- Each separate track corresponds to a branch in the protocol
- The lifelines may merge together at some subsequent point
  - AND parallelism starts at a horizontal heavy bar,
  - OR parallelism (inclusive-or) starts at a horizontal heavy bar with a non-filled diamond, and,
  - Decision (exclusive-or) starts at a horizontal heavy bar with a non-filled diamond with "x" inside the diamond
- And is continued with a set of parallel vertical lifelines connected to the heavy bar.

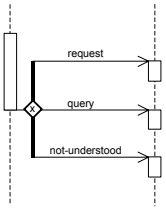
Threads of Interaction

- A tall thin rectangle whose top is aligned with its initiation time and whose bottom is aligned with its completion time.
- Drawn over the lifeline of an agent role
- Represents a task being performed
  - May be labeled as text next to the thread or in the left margin
  - The incoming message may indicate the task

Threads of Interaction



can be abbreviated as



Messages

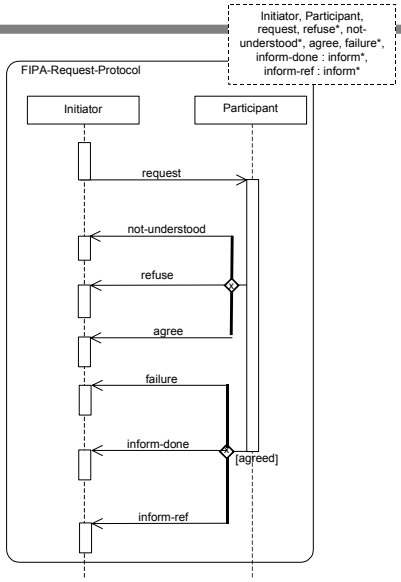
- Message - communication from one agent role to another that conveys information with the expectation that the receiving agent role would react according to the semantics of the communicative act
- Shown as a horizontal solid arrow from one thread of interaction to another thread of interaction
  - May be specified using AND/OR/XOR
- Each arrow is labeled using the following syntax:

```
predecessor guard-condition sequence-expression communicative-act argument-list
```

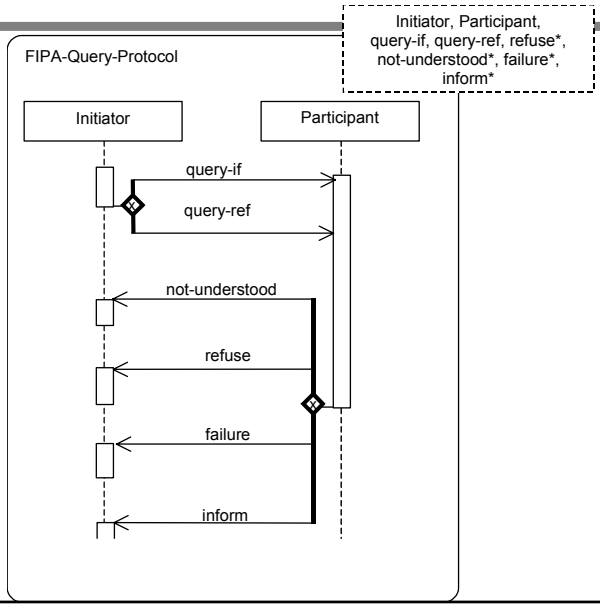

Messages

- predecessor - consists of at most one natural number followed by a slash (/) defining the sequencing of a parallel construct
- guard-condition - a usual UML guard condition - the message is sent iff the guard is true
- sequence-expression - a constraint, especially with n..m which denotes that the message is sent n up to m times
  - the keyword broadcast denotes the broadcast sending of a message
- communicative-act - the name of a communicative act, e.g., inform
- argument-list - a comma-separated list of arguments enclosed in parentheses - the parentheses can be omitted if the list is empty

Request Interaction Protocol



Query Protocol



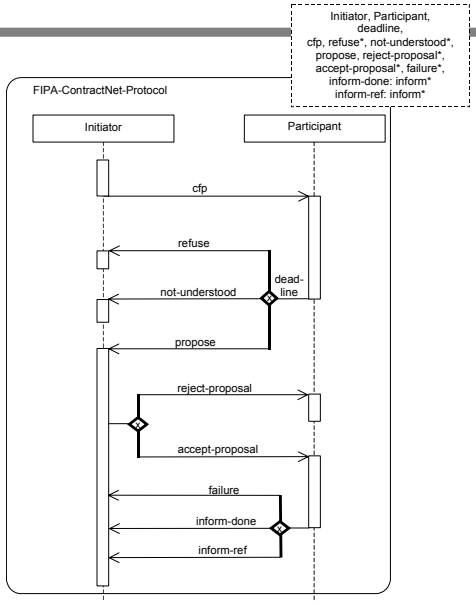
Cooperation Protocols

- To cooperate, tasks must be distributed – can use one of the following
  - Avoid overloading critical resources
  - Assign to agents with matching capabilities
  - Give one agent enough knowledge to make task assignments
  - Assign overlapping responsibilities to achieve coherence
  - Assign highly interdependent tasks to "related" agents
  - Reassign agents to handle urgent or critical tasks

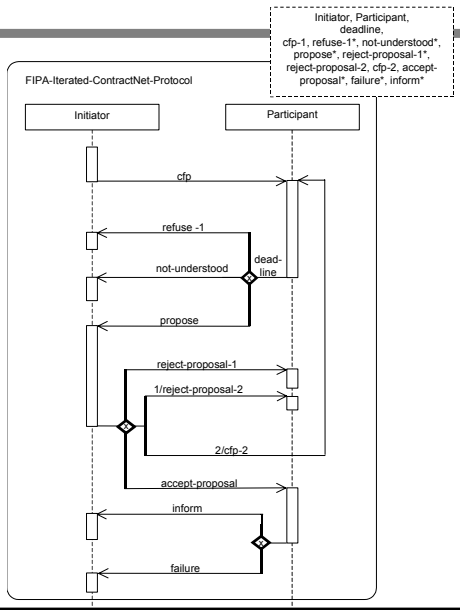
Cooperation Mechanisms

- There are many ways to distribute these tasks:
  - Fixed organizational structure
  - Multiagent planning
  - Contracting
  - Market mechanisms

Contract Net Protocol



Iterated Contract Net Protocol



Iterated Contract Net Protocol

The FIPA Iterated Contract Net Interaction Protocol (IP) is an extension of the basic FIPA Contract Net IP (see [FIPA00029]), but it differs by allowing multi-round iterative bidding. As with the FIPA Contract Net IP, the manager issues the initial call for proposals with the *cfp* act (see [FIPA00037]). The contractors then answer with their bids as *propose* acts (see [FIPA00037]) and the manager may then accept one or more of the bids, rejecting the others, or may iterate the process by issuing a revised *cfp*. The intent is that the manager seeks to get better bids from the contractors by modifying the call and requesting new (equivalently, revised) bids. The process terminates when the manager refuses all proposals and does not issue a new *cfp*, accepts one or more of the bids or the contractors all refuse to bid.

Negotiation Protocols

- A process by which a joint decision is reached by 2+ agents, each trying to reach in individual goal or objective
- Major features of negotiation
  - Language
  - Protocol
  - Decision process

Types of Negotiation

- Environment centered
  - How can the environment force agents to interact fairly and productively
- Agent centered
  - Given an environment, what is the best strategy for an agent to follow

Environment Attributes

- Attributes of a good environment include
  - Efficiency
  - Stability
  - Simplicity
  - Distribution
  - Symmetry

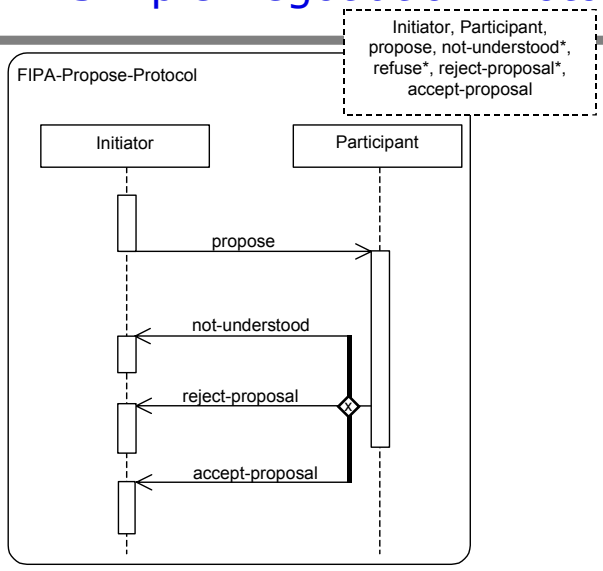
Agent Centered Negotiation

- Generally problem specific, but two general approaches
  - Formal – speech acts combined with possible worlds semantics
  - Economic rationality

Economically Rational Agent

- Based on the utility of a deal between agents
  - Negotiation set is the set of all deals with a positive utility for all agents
  - Three situations
    - Conflict
    - Compromise
    - Cooperative

Simple Negotiation Protocol



Market Mechanisms

- Allow large numbers of agents to work together without direct communication
- One scheme is voting
  - Simple
  - Equitable
  - Large communication and organization overhead

Computational Economies

- Everything of interest is based on price
- Two types of agents
  - Producers – transforms one good into another
  - Consumers – buy and sell goods
- Agents bid at various prices; However, all exchanges take place at the market price

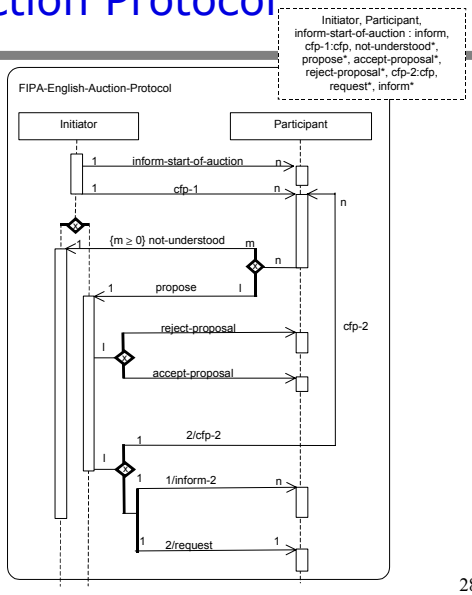
Effectiveness

- Markets for goods are interconnected thus price of one good will effect the supply and demand for others
- Market should reach competitive equilibrium
  - Consumers bid to maximize utility
  - Producers bid to maximize profits
  - Net demand for all goods is zero

Equilibrium

- *Competitive equilibrium* corresponds to some sense of optimality
  - An allocation of resources and activities among the agents
  - Equilibrium exists when an individual agent's affect on the economy is negligible

English Auction Protocol



English Auction Protocol

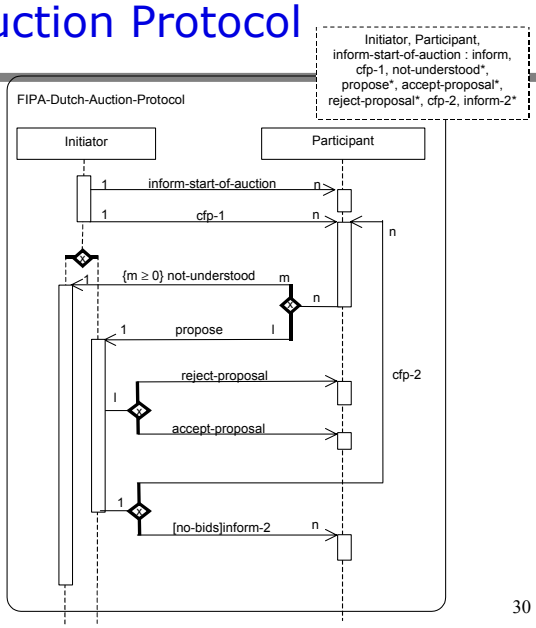
In the FIPA English Auction Interaction Protocol (IP), the auctioneer seeks to find the market price of a good by initially proposing a price below that of the supposed market value and then gradually raising the price. Each time the price is announced, the auctioneer waits to see if any buyers will signal their willingness to pay the proposed price. As soon as one buyer indicates that it will accept the price, the auctioneer issues a new call for bids with an incremented price. The auction continues until no buyers are prepared to pay the proposed price, at which point the auction ends. If the last price that was accepted by a buyer exceeds the auctioneer's (privately known) reservation price, the good is sold to that buyer for the agreed price. If the last accepted price is less than the reservation price, the good is not sold

In *Figure 1*, the auctioneer's calls, expressed as the general *cfp* act (see [FIPA00037]), are multicast to all participants in the auction. For simplicity, only one instance of the message is portrayed. Note also that in a physical auction, the presence of the auction participants in one room effectively means that each acceptance of a bid is simultaneously broadcast to all participants and not just the auctioneer. This may not be true in an agent marketplace, in which case it is possible for more than one agent to attempt to bid for the suggested price. Even though the auction will continue for as long as there is at least one bidder, the agents will need to know whether their bid (represented by the *propose* act - see [FIPA00037]) has been accepted. Hence the appearance in the IP of the *accept-proposal* (see [FIPA00037]) and *reject-proposal* acts (see [FIPA00037]), despite this being implicit in the English Auction process that is being modelled.

Note that the proposals that are submitted by the bidders primarily concern the bidding process. In response to a *cfp* to submit bids to purchase a good X, a proposal would be something of the order: "I propose that the bidding level be raised to purchase price Z and I assert that I am able to pay Z for X." This allows the auctioneer to be confident that the bidder can indeed pay the price without committing to actually paying it until the auctioneer specifically requests X (at price Z) from the winning bidder.

At the end of the IP, the auctioneer will typically enter a *request* IP (see [FIPA00026]) with the winning bidder to complete the auction transaction.

Dutch Auction Protocol

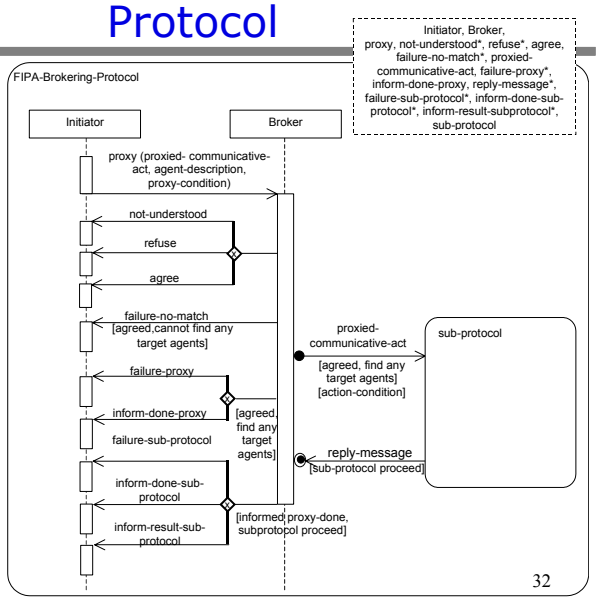


Dutch Auction Protocol

In the FIPA Dutch Auction Interaction Protocol (IP), the auctioneer attempts to find the market price for a good by starting bidding at a price much higher than the expected market value, then progressively reducing the price until one of the buyers accepts the price. The rate of reduction of the price is up to the auctioneer and they usually have a reserve price below which not to go. If the auction reduces the price to the reserve price with no buyers, then the auction terminates.

The term "Dutch Auction" derives from the flower markets in Holland, where this is the dominant means of determining the market value of quantities of (typically) cut flowers. In modelling the actual Dutch flower auction (and indeed in other markets), some additional complexities occur. First, the good may be split: for example the auctioneer may be selling five boxes of tulips at price X, and a buyer may purchase only three of the boxes. The auction then continues, with a price at the next increment below X, until the rest of the good is sold or the reserve price met. Such partial sales of goods are only present in some markets; in others the purchaser must bid to buy the entire good. Secondly, the flower market mechanism is set up to ensure that there is no contention amongst buyers by preventing any other bids once a single bid has been made for a good. Offers and bids are binding, so there is no protocol for accepting or rejecting a bid. In the agent case, it is not possible to assume, and too restrictive to require, that such conditions apply. Thus it is quite possible that two or more bids are received by the auctioneer for the same good. The protocol below thus allows for a bid to be rejected. This is intended only to be used in the case of multiple, competing and simultaneous bids. It is outside the scope of this specification to pre-specify any particular mechanism for resolving this conflict. In the general case, the agents should make no assumptions beyond "first come, first served". In any given domain, other rules may apply.

Brokering Interaction Protocol



Brokering Interaction Protocol

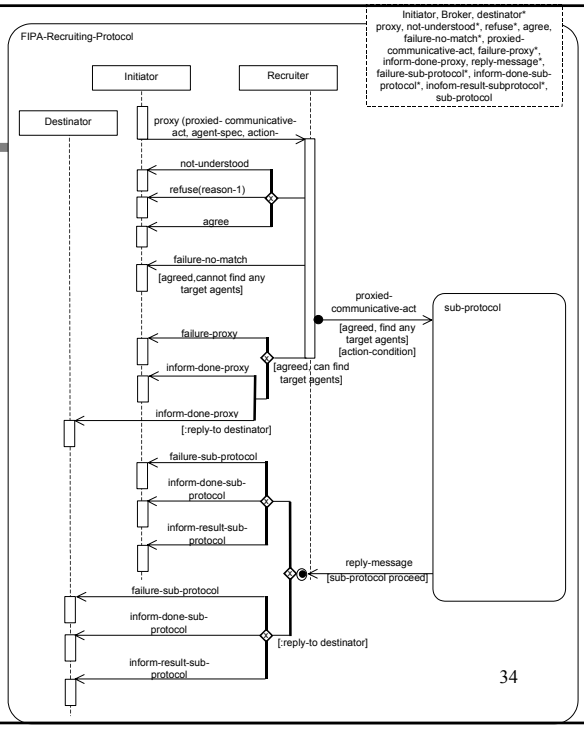
The concept of an information brokerage has been widely used in mediated systems and in multi-agent systems in particular (for example, see [Finin97]). The FIPA Brokering Interaction Protocol (IP) is designed to support these brokerage interactions in multi-agent systems.

Generally speaking, a broker is an agent which offers a set of communication facilitation services to other agents using some knowledge about the requirements and capabilities of those agents. A typical example of brokering is one in which an agent can request a broker to find one or more agents who can answer a query. The broker then determines a set of appropriate agents to which to forward the query, sends the query to those agents and relays their answers back to the original requestor. The use of brokerage agents can significantly simplify the task of interaction with agents in a multi-agent system. Additionally, brokering agents also enable a system to be adaptable and robust in dynamic situations, supporting scalability and security control at the brokering agent.

The FIPA Brokering IP is a macro IP, because the *proxy* communicative act (see [FIPA00037]) for brokerage embeds a communicative act as its argument and so the IP for the embedded communicative act is also embedded in this IP. When the embedded communicative act includes some actions that would be done by the agents determined by broker agents, then this IP would be extended for notifying the result of the actions.

The broker agent should record some of the ACL parameters (see [FIPA00061]), for example, `:conversation-id`, `:reply-with` and `:sender`, of the received *proxy* message to forward back the replying message to the corresponding original agent (the sender of the *proxy* message).

Recruiting Interaction Protocol



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In the case of recruiting, the answers from the selected target agents go directly back to the original requestor or some designated receivers. The use of brokerage agents can significantly simplify the task of interaction with agents in a multi-agent system. Brokering agents also enable a system to be adaptable and robust in dynamic situations, supporting scalability and security control at the brokering agent.

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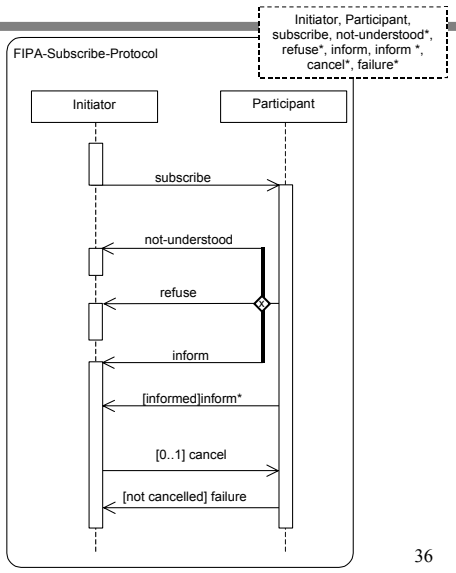
Subscribe Interaction Protocol



Subscribe Interaction Protocol

In the FIPA Subscribe Interaction Protocol (IP), an agent requests to be notified whenever a condition specified in the subscription message becomes true

Summary

- Commitments & conventions
  - Simple protocols
    - Request
    - Query
- Cooperation protocols
  - Contract Net
  - Negotiation
  - Market mechanisms
- Middle agent protocols
  - Brokering
  - Recruiting
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