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Abstract:

This document describes the activities performed in *WP2 - Simulation* in the third and final year of the CATNETS project. In particular, it focuses on WP2's main task namely, *Simulation of application layer networks and refinement*.

Keywords (optional):

CATNETS simulator, user guide, simulation environment refinement.

CATNETS Consortium

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Contents

Chapter 1

Introduction

The objective of *WP2 - Simulation* of the CATNETS project was to identify the required features of the CATNETS simulator, to develop it, and to incorporate the centralised and catallactic service/resource market specifications from *WP1: Theoretical and Computational Basis*. The simulator is to be used for controlled executions of Application Layer Network (ALN) scenarios. Results of executions are the basis of performance evaluation and comparison of the catallactic and centralised allocation mechanisms performed by *WP4 - Evaluation*.

The simulator is a component of the high level workflow depicted in Figure 1.1, which measures technical and economic metrics which the evaluation component uses for computation of several indicators. The components acting in the workflow are:

Scenario Generator. This component takes a set of scenario parameters as an input and produces a scenario to be simulated as an output.

Simulator. It takes a scenario as an input and executes it by using a service and resource allocation approach. The output of a simulation is a set of technical and economic metrics as described in Deliverable D4.1 [WP405].

Evaluator. This component takes a set of technical and economic metrics as input and, as described in Deliverable D4.1 [WP405], calculates an economical performance indicator for the allocation mechanism under observation.

The description of the components above is mainly given in Deliverables D2.2 [WP206] and D4.2 [WP406] produced in project year 2. This deliverable focuses on the activities performed by WP2 in the third and final year of CATNETS.

According to the work plan of the project, in year 3 WP2 was supposed to work on task *Simulation of Application Layer Networks and refinement*. In this document, the focus is on refinement i.e. on describing how the CATNETS simulator has been improved after the last review meeting. Detailed account on performed extensive ALN simulations

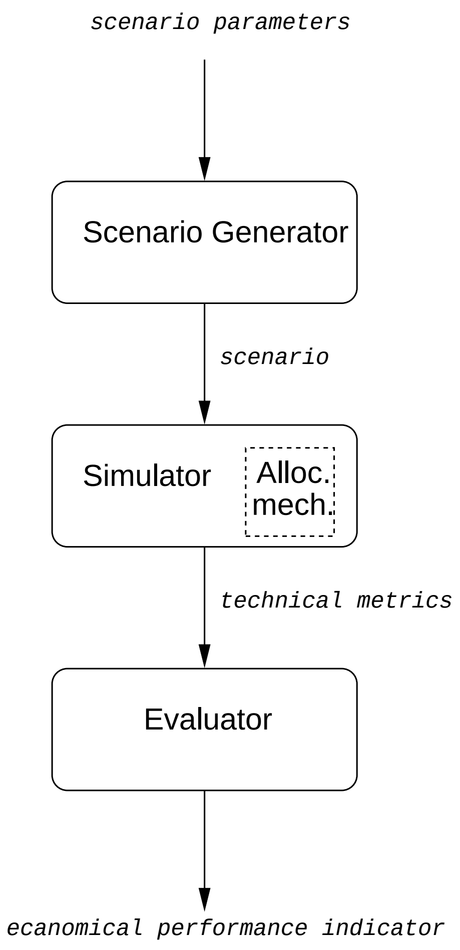


Figure 1.1: Architecture for evaluation system.

and simulations of prototype-like scenarios is given in Deliverable D4.3 [WP405], which includes a comprehensive report of experiments conducted to evaluate the catallactic and centralised allocation mechanisms.

Some directions for simulator refinement were identified and listed in Deliverable D2.2 [WP206]. Others derived from reviewers' comments and suggestions included in the CATNETS Review Report N^o 2. In summary, in project year 3 WP2 worked on the following refinement tasks.

Automated scenario generator. This tool was needed to produce large-scale scenarios to be simulated. Its implementation started in project year two and was concluded, as planned, at *T0+28*.

Message delivery failure. The simulator was extended by adding the possibility of modeling message delivery failure so that experiments could cover also more realistic scenarios were communication between ALN sites is error-prone. This task was completed by *T0+28*.

Link-load-dependent message latency. Variable message latency depending on bandwidth currently available between ALN sites was taken into consideration. A mechanism implementing this feature, already embedded in the base simulator OptorSim, was analysed, adapted and included in the CATNETS simulator. This task was completed, as planned, by *T0+30*.

Event-driven time model. The base simulator OptorSim offered two time models, one time-based and one event-driven. In the last year of the project, the event-driven time model was adopted and embedded into the CATNETS simulator. This task ended at *T0+32*.

Refinement of centralised mechanism. Some modifications to the implementation were done in order to increase the service/resource allocation rate when the centralised allocation mechanism is adopted. This task was completed by *T0+28*.

Refinement of catallactic mechanism. This tasks involved some bug fixing and the implementation of resource co-allocation. It has been completed by *T0+32*.

Full implementation of metrics. At the end of project year 2, the CATNETS simulator implemented the recording of a subset of the technical metrics defined by WP4 in Deliverable D4.1 [WP405]. The implementation of the metrics framework was completed at *T0+31*.

The issues listed above are described in Chapter 2. In particular, Section 2.1 describes the automated scenario generator while Section 2.2 presents the enhancements to the simulator's messaging system and time model. Sections 2.3 and 2.4 show the implementation refinements of the centralised and catallactic markets. Finally, Section 2.5 gives an account on the full implementation of technical metrics and their semantics.

In the rest of the document, Chapter 3 is a user guide which explains how to conduct simulations and Chapter 4 summarizes the achieved results and gives directions about how the CATNETS simulator can be further extended.

Chapter 2

Simulator refinement

2.1 Automated scenario generator

The CATNETS automated scenario generator is a tool used for the generation of scenarios to be given as an input to the CATNETS simulator. In Deliverable D2.2 [WP206] the requirement for this tool were identified. In this section, the focus lies on its implementation.

The automated generator is based on BRITE [MLMB01b] a topology generation framework which is able to generate synthetic topologies that accurately reflect many aspects of the actual Internet topology. BRITE supports multiple generation models including models for flat AS, flat Router and hierarchical topologies. Models can be enhanced by assigning links with attributes such as bandwidth and delay.

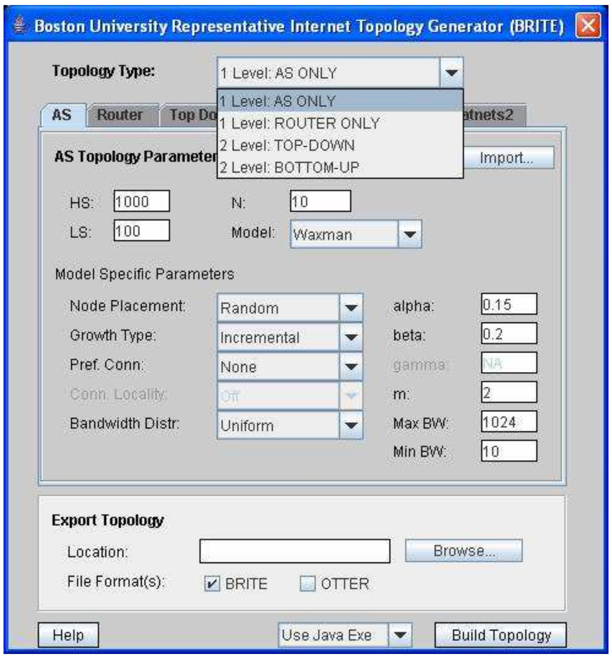
Figure 2.1 shows how to choose the topology model in BRITE. For details about how to use BRITE the reader is referred to the BRITE user manual [MLMB01a]. BRITE was extended in order to obtain an automated scenario generator which is able to generate scenarios compliant to the ALN model presented in Deliverable D2.2 [WP206].

2.1.1 Extensions

Two tabs have been added to the GUI of BRITE. They are called `Catnets1` and `Catnets2` and are shown in Figure 2.2 and Figure 2.3, respectively.

Catnets1 - Tab

Tab `Catnets1` enables the configuration of complex service types, basic service types, and resource types, which equal the products available in the application layer network. The following parameters are included in the tab:



Topology Type: 1 Level: AS ONLY

HS: 1000
N: 10
LS: 100
Model: Waxman

Node Placement: Random
alpha: 0.15
Growth Type: Incremental
beta: 0.2
Pref. Conn: None
gamma: NA
Conn. Locality: Off
m: 2
Bandwidth Distr: Uniform
Max BW: 1024
Min BW: 10

Location:
File Format(s): [✓ BRITE] OTTER

Figure 2.1: BRITE topology selection.

Resource parameters. The user can define $\#Res$, the number of resource types available in the scenario, and $Qmax$, the maximum quantity for each resource type. $\#Res$ resources will be created, each of which having a quantity defined by a random integer in the range $[1, Qmax]$.

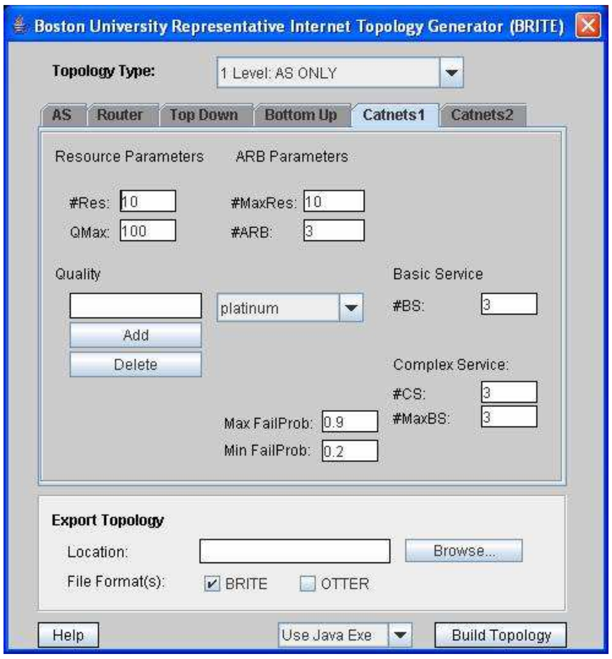
ARB parameters. The user can define $\#MaxRes$, the maximum number of resources per Available Resource Bundle, and $\#ARB$, the number of ARBs. $\#ARB$ ARBs will be created, each of which including a number of resources defined by a random integer in the range $[1, \#MaxRes]$.

Quality. The user can add and delete values for the quality of basic services.

Basic Service. The user can define $\#BS$, the number of basic service types.

Complex Service. The user can define $\#CS$, the number of complex services, and $\#MaxBS$, the maximun number of Basic services per CS. $\#CS$ complex services will be randomly created, each of which including at most $\#MaxBS$ basic services.

Failure probability. The user can define a range for the site failure probability. Every site will fail with a probability in the range $[MinFailProp, MaxFailProp)$.



Topology Type: 1 Level: AS ONLY

Resource Parameters

#Res: 10
QMax: 100

ARB Parameters

#MaxRes: 10
#ARB: 3

Quality: platinum

Basic Service

#BS: 3

Complex Service:

#CS: 3
#MaxBS: 3

Max FailProb: 0.9
Min FailProb: 0.2

Export Topology

Location:
File Format(s): [✓ BRITE] OTTER

Use Java Exe

Figure 2.2: Automated scenario generator: `Catnets1` parameter tab.

Catnets2 - Tab

This tab allows the configuration of the complex service, basic service and resource instances. Distributions are available which assign the instances to network nodes. The following parameters can be defined:

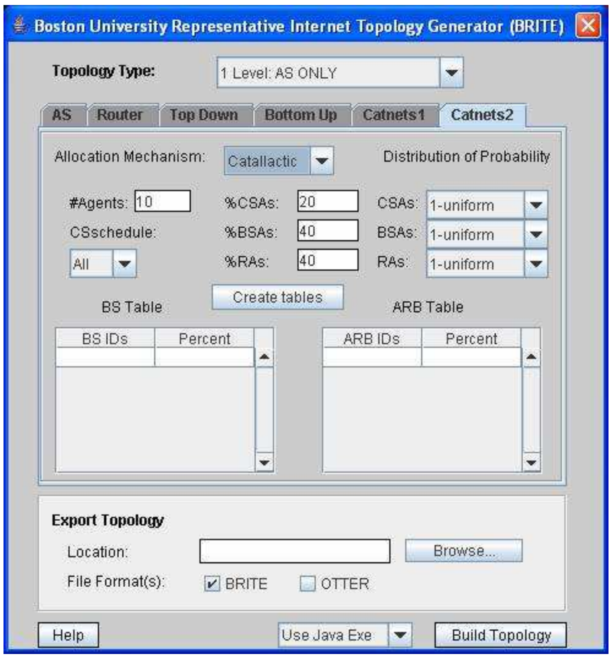
Allocation mechanism. The user can set the allocation mechanisms, *catallactic* or *centralised*, for which the scenario is being created.

CS schedule. The user can decide if all the Complex Service Agents can run all complex services or if CSAs can run only a subset which is randomly chosen.

Agents definition and distribution. The user can define $\#Agents$, which is the total number of agents to be placed in the ALN, the percentages of complex service agents ($\%CSAs$), basic service agents ($\%BSAs$) and resource agents ($\%RAs$) and the distributions of probability used for the placement of agents in the ALN. The following distributions are available:

Uniform. The site for the agent is chosen using uniform probability distribution.

Links (dir). The site for the agent is chosen with probability proportional to the number of site links (the more the site is connected, the greater the probability it host agents).



Boston University Representative Internet Topology Generator (BRITE)

Topology Type: 1 Level: AS ONLY

Allocation Mechanism: Catallactic

Distribution of Probability

#Agents: 10
CSschedule: All
%CSAs: 20
%BSAs: 40
%RAs: 40
CSAs: 1-uniform
BSAs: 1-uniform
RAs: 1-uniform

Export Topology
Location:
File Format(s): [✓ BRITE] OTTER

Figure 2.3: Automated scenario generator: `Catnets2` parameter tab.

Links (inv). The site for the agent is chosen with probability inverse proportional to the number of site links. The more the site is connected, the smaller is the probability to host agents.

Dist (dir). The site for the agent is chosen with probability proportional to the distance between the site and a pivot site (the more the distance, the greater the probability).

Dist (inv). The site for the agent is chosen with probability inverse proportional to the distance between the site and a pivot site (the less the distance, the greater the probability).

Percentage of BSAs providing a specific types of basic service. The user can decide the percentage of agents providing a specific type of basic service. By clicking on the `Create Tables` button, the predefined percentages are shown and the user can modify them.

Percentage of RAs providing a specific available resource bundles. The user can decide the percentage of agents providing a specific ARB. By clicking on the `Create Tables` button, the predefined percentages are shown and the user can modify them.

2.1.2 How to generate a scenario

Once all the parameters have been set, a folder has to be selected for the output files. A click on the button `Build Topology` generates the scenario.

Four input files for the CATNETS simulator are created:

- `topology.conf`: specifies the ALN topology;
- `cs.conf`: specifies the complex services;
- `bs.conf`: specifies the basic services;
- `arb.conf`: specifies the available resource bundles;

Two additional files are created:

- `<filename>.brite`: specifies the topology in BRITE format;
- `<filename>.odf` (optional): specifies the the topology in OTTER format (see `http://www.caida.org/tools/visualization/otter/`).

`<filename>` can be specified by the user.

2.2 Infrastructure

2.2.1 Message delivery failure

The communication system of the CATNETS simulator, developed in project year 2, features both point-to-point and broadcast/multicast communication. These communication paradigms are used to implement the negotiation protocols adopted in the centralised and catallactic markets. In real networks, the delivery of point-to-point or brodcast/multicast message can fail, the possibility of simulating failure of ALN links has been added to the CATNETS simulator in project year 3.

Given the base simulator OptorSim, the failure probability was associated to ALN sites instead of links because of easier implementation:

1. Every ALN site has a given failure probability f_p. This is a static parameter specified in the configuration file `topology.conf`. The failure probability can be specified using either the manual or automated scenario generators.

2. The site failure probability f_p is used by P2P mediators located in every site[1]: whenever a P2P mediator is requested to delivery a message, the message is forwarded to the recipient(s) with a probability $p = 1 - f_p$.

If the failed message is a point-to-point message, a single agent will not receive it. In other words the link between one sender and one receiver agent is not working. If the message is a multicast/broadcast message, the P2P will not propagate it to neighbour sites and multiple agents will not receive it. In this case, the site failure probability can be interpreted as the failure of all site's out-links.

This implementation of message delivery failure permits the simulation of a wide range of real situations, including the real world characteristic that failure of broadcast/multicast delivery has certainly a greater overall impact on the course of simulation than point-to-point delivery failure.

2.2.2 Link-load-dependent message latency

The CATNETS simulator has been refined by adding the possibility of simulating delivery of messages dependent on the current network traffic (i.e. how much bandwidth is consumed by the messages currently being delivered) along the path between sender and receiver.

The message transfer implementation provided by OptorSim was adapted. Every message transfer between sites is handled by an instance of the class `MessageTransfer`. This class takes care of message transfers over the simulated ALN. It notifies other `MessageTransfer` instances that it is starting (and therefore changing the network situation) and waits until the transfer is complete. If the waiting is interrupted by another `MessageTransfer` start, the time left to transfer the message is recalculated based on the new network load. The `MessageTransfer` instance which started before waits again until the transfer is complete. When the transfer has finished, it notifies all the other currently running `MessageTransfer` instances.

2.2.3 Event-driven time model

The base simulator OptorSim includes two time models to be used for simulation, one time-based and one event-driven time model. Simulation runs with both time models delivering the same end results. In project year 3, the event-driven time model was adopted for the CATNETS simulation scenario.

In the time-based model, the simulation proceeds in real time. The simulation time equals the wall clock time to complete a simulation run by simulating all complex service

[1]P2P Mediators deal with management of all messages: when a message has to be sent by an agent located on a site, actual delivery (also to other local agents) is performed by the local P2P mediator.

requests.

In the event-driven model, the simulation time is advanced to the point when the next thread should be activated. The use of the event-driven model speeds up the running of the simulation considerably, whereas the time-based model may be desirable for demonstration or debugging purposes.

The event-driven time model is implemented by using a thread called `TimeAdvancer` which controls the advance of time. The thread runs as a lowest priority thread which only starts working in general when all other threads are sleeping. When it runs, it continually checks to see if all other threads are sleeping. If there are all threads sleeping, it finds out the thread which should be activated again. It advances time to this point and wakes up the thread.

2.3 Centralised market

In the second project year, we conceptualized a model for generating values for the bids in the central case [WP106]. The purpose of the model was to determine *what* and *when* an agent bids in the auctioneer cases. *What* denotes the valuation and the reservation prices of agents, i.e. the maximal price which an agent is willing to pay for a service (resp. the minimum price an agent has for selling a service). *When* denotes the timing of bids, i.e. which event induces an agent to bid for a service. Both cases are different in the central and decentral scenario. As such, it was important to find concepts that are applicable for both scenarios and, thus, make the results comparable. As a result, a rather complex model was developed with the aim of imitating the co-evolutionary learning algorithms [WP106], which is used in the catallactic allocation approach.

Preliminary simulation runs evinced that the model was too complex to analyze and to identify specific effects of the implemented auction mechanisms. This originates in the fact that too many parameters of the model influenced the overall outcome. As a consequence, the reasons for particular outcomes cannot be easily identified.

In order to observe and identify specific effects of the auction mechanisms, a simpler bidding model was developed in the third project year. Valuation and reservation prices of agents are drawn from a normal distribution where mean and standard deviation can be set by means of a configuration file. As the simulation scenarios show, the simpler model allows a more profound analysis of the metrics to be observed.

Both models can be selected by means of a configuration file (see Section 3.2.2 for details).

2.4 Catallactic market

The components of the Catallactic strategy, presented in Deliverable D1.1 and formalized in Deliverable D2.1, were optimized during the simulation of several test scenarios in project year 3. A configuration file was introduced for defining the traded products on the Catallactic market, which enables the configuration of the catallactic market properties (see subsection 2.4.1). Besides the configuration of the Catallactic market properties, all parameters of the Catallactic strategy could be configured with configuration files, too. Subsection 2.4.2 presents a visual tool for generating the market properties which eases the creation of the market product configuration file. Improvements to the strategy are presented in the following subsections. In subsection 2.4.3, a performance analysis of the flooding algorithm is introduced. Several simulation runs evidenced that the performance of the discovery algorithm has large impact on the allocation performance in the Catallactic allocation approach. The performance analysis gives advice how to set the number of hops for the flooding algorithm.

A simplified Catallactic strategy implementation is presented in subsection 2.4.5. Instead of using a iterative bargaining with several negotiation rounds, this strategy uses only one negotiation round for reaching an agreement. This helps to reduce the messaging complexity of the Catallactic iterative bargaining implementation.

2.4.1 Configuration of the Catallactic market

The configuration of the Catallactic market includes the initialisation of the traded products, its price ranges and several constraints of the Catallactic market. These constraints improve the performance of the Catallactic strategy in the examined scenarios. A detailed description of the Catallactic market configuration contains the following properties:

- Service market products: Each basic service type (BS_i), which is traded on the service market, has to be configured for the Catallactic strategy. The complex service agent as a buyer and the basic service agent as a seller of the service can be configured with its initial trading price range setting a minimum and a maximum price (minPrice and maxPrice). The hard lower and upper limits are additional constraints preventing usuary bids. A seller will never sell his basic service below the given lower limit whereas a buyer will never submit a bid higher than his budget (hard upper limit). All basic services instances of the same type use the same hard lower and upper limits. The next configuration parameter assigns resource bundles to the given basic service type. This allows a basic service agent to choose between different resource bundles and buy them on the resource market. The order of the resource bundles is important, a bundle at first place has higher preference than a bundle at second place. If there is a list resource bundles, the co-allocation switch of the simulator has to be turned on. This allows the basic service agent to buy from more than one resource provider. The basic service agent tries to fulfill his resource demand with the resource bundle specified at the first place before he selects a resource bundle of the second specified type ($resource.itemids$).

$< BS_i >$ $.seller.minPrice =< double >$
$< BS_i >$ $.seller.maxPrice =< double >$
$< BS_i >$ $.buyer.minPrice =< double >$
$< BS_i >$ $.buyer.maxPrice =< double >$
$< BS_i >$ $.hard.lower.limit =< double >$
$< BS_i >$ $.hard.upper.limit =< double >$
$< BS_i >$ $.resource.itemids =< RB_1 > ... < RB_n >$

An example configuration is presented below. Both the complex service agents and the basic service agents start with the same initial price range. The budget of the complex service is 50, the minimum costs for the basic service (bs1) is 20. This lower bound can be seen as the production costs for a basic service provider. Both, the seller and buyer start with the same price range between 25 and 40. The specified basic type is only allowed to buy resources of product $r1$.

```
bs1.seller.minPrice = 25
bs1.seller.maxPrice = 40
bs1.buyer.minPrice = 25
bs1.buyer.maxPrice = 40
bs1.hard.lower.limit = 20
bs1.hard.upper.limit = 50

bs1.resource.itemids = r1
```

- Resource market products: The reason for specifying resource market products is the general demand of resources in the basic service configuration. The strategy works on product level. This means the catallactic reasoner estimates his price for a given set of traded products. For a resource bundle of the basic service configuration, either each single resource is traded and its prices are summed up or a predefined set of resource bundles can be traded on the resource market. The Catallactic mechanism chooses the second option which allows a more flexible way to trade products on the resource market. We assume, there are base resources on the market. Each resource provider defines his individual set of resource bundles and price ranges and shares the intended meaning with the basic service. In the service market configuration, the basic service consumer defines which of these resource bundles can be bought to fulfill his resource demand on the resource market.

  A resource provider defines its resource product out of a set of basic resources and chooses an arbitrary name for the resource bundle. The resource bundle determines the base units of each resource. A resource consumer requests a multiple of these resource bundle base units. Like in the service market configuration, the same initial resource market price s has to be configured along with the initial minimum and maximum prices for buyers and seller, which trade this product and hard upper and lower limit prices. The lower limit price is the minimum price a resource provider is willing to sell this product and the hard upper limit price is the budget of the resource consumer. Finally, each resource provider reads the list of possible resource products ($arb.itemids$) and decides according to his available resource items, if he is able to provide this resource product.

$< resource\_product\_id > .resourceids =< resource_1 > ... < resource_n >$
$< resource\_product\_id > .baseunit. < resource_1 >=< int >$
...
$< resource\_product\_id > .baseunit. < resource_n >=< int >$
$< resource\_product\_id > .seller.minPrice =< double >$
$< resource\_product\_id > .seller.maxPrice =< double >$
$< resource\_product\_id > .buyer.minPrice =< double >$
$< resource\_product\_id > .buyer.maxPrice =< double >$
$< resource\_product\_id > .hard.lower.limit =< double >$
$< resource\_product\_id > .hard.upper.limit =< double >$

$arb.itemids =< resource_product_id_1 > ... < resource_product_id_n >$

An example of one resource product is shown below. The resource bundle consists of three base resources. Multiples of 1 ram unit, 2 cpu units and 1 storage unit are tradeable. Both, resource buyer and resource seller start with the same initial price range. The budget of the buyer is set to 50 and the seller's minimum price is 20. There is only one product tradeable on the resource market. The resource providers check, if they are able to provide resource bundle $r1$.

```
r1.resourceids = ram cpu storage
r1.baseunit.ram = 1
r1.baseunit.cpu = 2
r1.baseunit.storage = 1
r1.seller.minPrice = 25
r1.seller.maxPrice = 40
r1.buyer.minPrice = 25
r1.buyer.maxPrice = 40
r1.hard.lower.limit = 20
r1.hard.upper.limit = 50

arb.itemids = r1
```

2.4.2 Market Property Generator

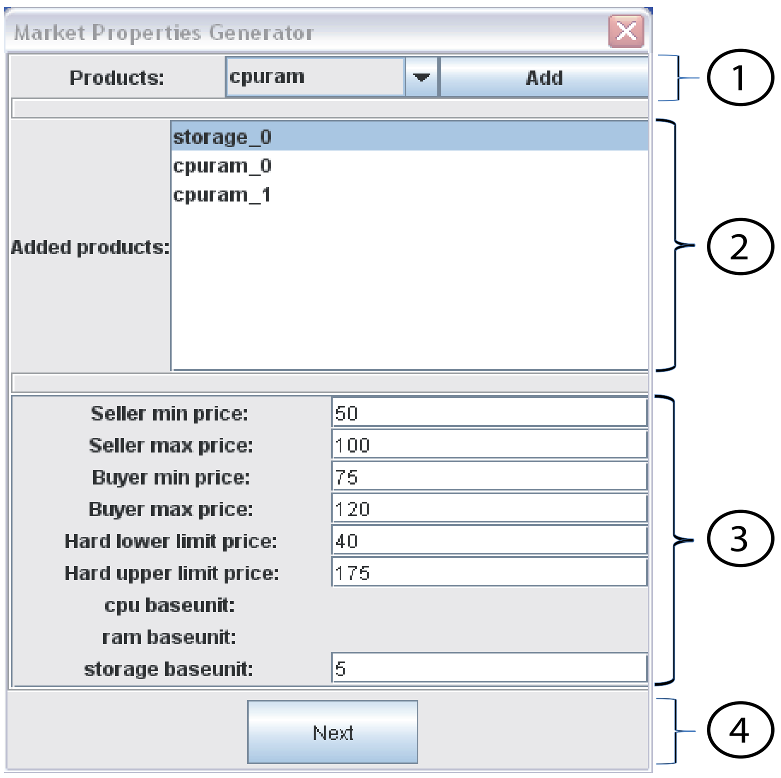
A visual tool, the market property generator (MPG), was developed to help creating this property file for the catallactic market configuration. The market property generator reads the *arb.conf* and *bs.conf* files which are created by the manual or automated scenario generator. These files are expected to be in the root directory of the market property generator.
The process of generating the market property file is divided into two steps which are illustrated by two screens respectively. Within step one, tradable products on the resource market are specified. In a second step, pricing limits are set for each basic service type and a resource product is assigned to each basic service type. An outline is given for both steps, which are illustrated by an example in the following.

Specification of Products

Starting the MPG will result in the screen depicted in Figure 2.4. This screen is divided into four different regions. Within region 1 all possible product types are shown in a drop down box. By selecting one of these types the user is enabled to instantiate a product type by pressing the *add* button on the right. Every instantiated product will appear in region 2. Instances of the same type are distinguishable by means of a number behind the identifier. Marking a single instance of a product type in region 2 makes it possible to customize it within region 3. Here, all product specific options are addressable. After customizing the products listed in region 2 the *next* button in section four hast to be pressed.
Figure 2.4 shows a snapshot of MPG which uses the example data provided below. Two different product types are instantiated, *storage* (one instance) and *cpuram* (two instances). The screen shot shows the available option for product *storage 0*.

```
#
# Available resource bundles
#
arb cpu 30
arb ram 40 storage 80


#
# Basic services
#
bs1 bs1 silver storage 10
bs2 bs2 silver cpu 20 ram 88
bs3 bs3 silver cpu 22 ram 22
```



Products: cpuram

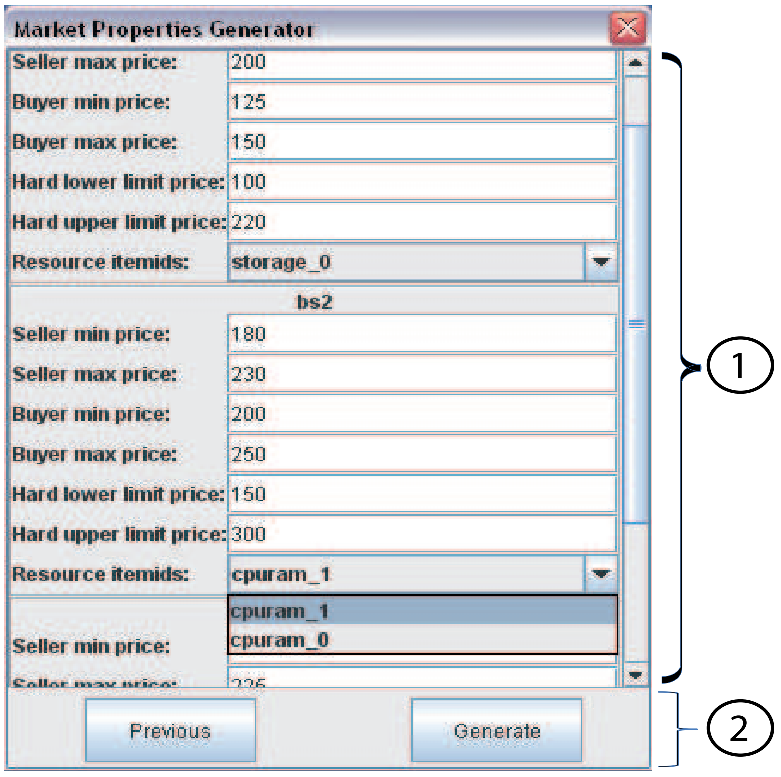
Added products:
storage_0
cpuram_0
cpuram_1

Seller min price:	50
Seller max price:	100
Buyer min price:	75
Buyer max price:	120
Hard lower limit price:	40
Hard upper limit price:	175
cpu baseunit:	
ram baseunit:	
storage baseunit:	5

Figure 2.4: Screen one of MPG.

Products and basic services

The second screen of MPG is depicted in Figure 2.5 which is divided into two regions. In region 1, every basic service type is enumerated with its specific options. Each of those options has to be changed by the user. The final option is presented in a drop down box. This box assigns a resource product to each particular type of basic service. If the box is empty, no resource product has been defined previously. Pressing the *previous* button allows the user to proceed on screen one. The *generate* button produces the catallactic market properties file.
Figure 2.5 shows the configuration for the example data set. In that specific case, there are two different products which could serve *bs2* needs. The user needs to choose which one he wants to assign to his basic service type.



Seller max price:	200
Buyer min price:	125
Buyer max price:	150
Hard lower limit price:	100
Hard upper limit price:	220
Resource itemids:	storage_0
bs2	
Seller min price:	180
Seller max price:	230
Buyer min price:	200
Buyer max price:	250
Hard lower limit price:	150
Hard upper limit price:	300
Resource itemids:	cpuram_1
	cpuram_1
Seller min price:	cpuram_0

Figure 2.5: Screen two of MPG.

2.4.3 Service and Resource Discovery

Large-scale Grids will borrow some of the characteristics of today's P2P systems in resource participation: unreliable resources and intermittent participation will constitute a significant share. This environment is likely to scale to thousands of resources shared by thousands of participants; no central, global authority will have the means and the incentive to administrate such a large collection of distributed resources. The nodes offer resource bundles as a service or application services (basic services and complex services) that other nodes (services) want to use. An issue central to such Grids is how to locate a service in the distributed system that provides it. There are various approaches to service discovery. In CATNETS, we consider a decentralized discovery mechanism based on flooding. With flooding a node that wants a particular resource or service contacts all neighbours in the system, which in turn contact their own neighbors until a node that provides the requested service is reached. Flooding enables resource discovery without directories or knowledge about the specific topology of the system, thus, offering an attractive mechanism for resource discovery in dynamically evolving systems.

In abstract terms, we assume a distributed system with N nodes where each node provides a number of resources or services. There are R different types of resources, which use the configuration explained in the previous section. Each node knows about d other nodes called neighbours. The system is modelled as directed graph G(V, E) where each node of the graph corresponds to a node of the distributed system and there is an edge from A to each node A's neighbours. Because each edge in G may not correspond to a physical link, graph G is called the overlay network. There is no knowledge about the size of the network.

We assume an overlay network where each node has d neighbors and maintains no cache about former searches. When a node A needs a particular type of resource or service x, it always floods the network with its call-for-proposal messages. Node A sends a message querying all or a subset of its neighbors, which in turn propagate the message to their neighbors, and so on. To avoid overwhelming the network with search requests, search is limited to a maximum number of steps t (similar to the Time To Live (TTL) parameter in many network protocols). In particular, the search message contains a counter field initialized to t. Any intermediate node that receives the message first decrements the counter by one. If the counter value is not 0, the node proceeds as normal; otherwise the node does not contact its neighbours. A node sends only a positive response to the inquiring node if x is found and has enough free capacity.

When the search ends, the inquiring node A will either have the contact information for resource x or nothing if all resources are used or currently down due to a failure. In the latter case, node A assumes that a node offering the resource cannot be found.

The implemented search strategy is pure flooding. With pure flooding, a node A that searches for a resource x checks its local resource and contacts all its neighbours. In turn, A's neighbours check their local resources and propagate the search message to all their neighbours. The procedure ends when either the resource is found or a maximum of t steps is reached. The scheme, in essence, broadcasts the inquiring message.

In the CATNETS simulator, the number of hops is controlled by two parameters because of different broadcast messages:

- Call-For-Proposal and Announce message hop count: The Call-For-Proposal message broadcast the demand to available seller within the given hop limit. An Announce message informs all agents about the results of the discovery phase. The behaviour is the following: A Call-For-Proposal message receiver blocks its basic service instance or resource bundle until an announce message is received. If the number of hops is high, the requestor of e.g. a basic service gets a higher number of basic services for selection, but blocks these basic service for any other requests until the announce message is received. This blocking policy leads to a low allocation rate of the system for a high number of hops defined in the hop count parameter and produces a high number of messages which have to be sent over the P2P network. Addressing both problems, the number of hops should be kept fairly low to 2 or 3 hops for a network with a high density of available services or resources. If there is a low density of available services, this number should be increased. To overcome the problems of the implemented blocking policy, the discovery time of a requestor (the time to receive an answer for a call-for-proposal message) is randomized. This gives the seller agents the opportunity to respond to other call-for-proposals, whenever they receive a reject with an announce message for the current selection. If the requestor would like to execute a long running service, there is the possibility to specify a counter of how many discovery time periods a requestor should wait receiving an answer for his call-for-proposal message. Of course, this increases the overhead time until the service execution can start.

In the example implementation below, a requestor decides to wait 10 times a randomized discovery timeout until he gives up his search for a basic service instance or a resource bundle.

```
Random rand = new Random();
_time.gtSleep((int)(_params.getDiscoveryTimeout())+
 Math.round((int)(_params.getDiscoveryTimeout())
           *rand.nextDouble()));

while (_proposals.isEmpty()&&discoveryCounter<10) {
_time.gtSleep((int)(_params.getDiscoveryTimeout())+
 Math.round((int)(_params.getDiscoveryTimeout())
               *rand.nextDouble()));
discoveryCounter++;
}
```

- Learning message hop count: This hop counter controls the speed of spreading plumages to other agents of the same role. The number of hops should also kept low because of the increasing number of messages which are needed to flood the network with new plumage information.

2.4.4 Configuration of the catallactic strategy and learning algorithm

In year 3 of the project the parameters of the catallactic strategy and the learning algorithm were externalized to ease the configuration for simulation runs. Two configuration files were introduced:

- strategy.conf: This file contains a the configuration of the catallactic strategy. The *dealRange* property defines which policy to use for adapting the deal range after a negotiation. The value *fixed* leads to not changing the deal range after a negotiation. The price ranges of the market configuration stay the same in every negotiation during the simulation run. The *static* policy adapts the price range according to the *priceNext* parameter of the genotype. The length of the deal range stays the same as defined in the market configuration. The *fixed* and *static* policies don't take into account the market price estimation for changing their deal range. This feature is provided by the *dynamic* policy. This policy uses the estimated market price of the agent to create the new deal range. The estimated market price is median of the deal range, its lower and upper bounds are computed using the *priceNext* parameter.

  Finally the *ringSize* parameter specifies how many prices of successful negotiations an agent should store before he forgets these achievements. Low values lead to high jumps of the markets prices whereas high values lead to very slow adaption to new market prices.

  ```
  # This file configures the catallactic strategy

  # modify deal range
  # values: fixed, static, dynamic
  dealRange = dynamic

  # ring size
  ringSize = 40
  ```

- learning.conf: This file initializes the genotype of the strategy and sets parameters of the co-evolutionary learning algorithm. The *maturityThreshold* and the *courterThreshold* properties control the sending and receiving of plumages. In the example setting below, an agent waits 5 successful negotiations until he broadcasts his plumage, whereas he would wait for 20 incoming plumages until he selects one for crossover. The *crossoverProbability* defines the probability for a gene to be selected for crossover. The CATNETS strategy has 5 genes: acquisitiveness, satisfaction, priceStep, priceNext and weightMemory. If the crossover parameter is set to 0.20, one gene is chosen on average for crossover in every selection round. A mutation step follows the crossover and is performed after every successful negotiation. The property *mutationProbability* defines the probability for a gene to be mutated. The *ringSize* parameters stores the agreement prices of an agent in an ring array which is used for market price computation. There are two policies implemented concerning how to select a genotype for crossover. The first policy selects one plumage which is better than my own current plumage whereas the second policy selects the best received plumage for crossover. The property *crossOverSelectionModel* sets this selection policy. In CATNETS, all genes are float genes with values between $/]0, 1/[$. To prevent the genes to reach 0 or 1, there is the possibility to set the maximum value the genes are allowed to reach with the properties *min* and *max*. An important value is the size of the mutation step. This size is set by the *gaussWidth* parameter. A random value is drawn from a gaussian distribution with the given width and added to the selected gene. In the example, the *gaussWidth* parameter is set to 0.01. This results in small changes of the genotypes. The last section of the configuration file controls the initialisation of the genotype. There is the possibility to start the simulation environment with a randomized genotype or a fixed genotype for all agents. For a detailed explanation of the genotype, we refer to Deliverable D2.2.

```
# setup learning

# send plumages
maturityThreshold = 5

# receive plumages
courterThreshold = 20

# crossover probability
crossoverProbability = 0.20

# mutation probability
mutationProbability = 0.70

# ring size
ringSize = 100

# crossOverSelectionModel
# (0) select plumages which are better than my plumage
# (1) select best received plumage
crossOverSelectionModel = 0

# init float gene
gaussWidth = 0.01
min = 0.001
max = 0.999
```

```
# setup genotype

# randomize genotype
# values: yes/no
genotype.randomize = no

# if randomize == no, use this genotype
genotype.acquisitiveness = 0.05
genotype.satisfaction = 0.99
genotype.priceStep = 0.5
genotype.priceNext = 0.05
genotype.weightMemory = 0.9
```

2.4.5 Simplified Catallactic strategy

The catallactic strategy uses bilateral bargaining, which comes along with a high number of messages to be transferred between the trading partners. To reduce this number of messages, a simplified version of the Catallactic strategy was implemented. This simplified strategy uses the same discovery mechanism. The ranking of received proposals is done according to its price. Instead of starting a bilateral bargaining with the cheapest proposal, the simplified strategy accepts the proposal, if this proposal is lower than his budget. The following learning step remains the same.

2.5 Metrics

This section presents the final set of metrics implemented in the simulation environment. The metrics are measured during simulation runs and stored in several text files. Analysis scripts use these text files and compute the metrics pyramid. In detail, the files are:

- Filename: accepts.txt
  Description: This file records the successfully ended negotiations (accept) for one simulation run. Each accept equals one entry in the accepts file.
  Sample entries:

  ```
  3725 CSA5@Site20 BSA0@Site24 accepts Negotiation0 seller
  6534 CSA0@Site3 BSA0@Site5 accepts Negotiation2 buyer
  ```

  Column description: time stamp in milliseconds (long), ID of the agent (String), ID of the agent (String), name of metric (String), negotiation id (String), role (String, buyer or seller which made the acceptance decision)

- Filename: basic_service_allocation_time.txt
  Description: This file lists the start and end events of basic service allocations. Both events are recorded by a complex service agent. A complex service agent measures the start event, when he issues a new basic service request. When a complex service agent receives an end of negotiation signal, he adds the end event to the basic service allocation time file. Using these start and end events, the basic service allocation time is computed as the different between the start and end event time.
  Sample entries:

  ```
  3000 CSA5@Site20 basic_service_allocation_time
      start Negotiation0
  3740 CSA5@Site20 basic_service_allocation_time
      end Negotiation0 success
  ```

  Column description: time stamp in milliseconds (long), ID of the agent (String), name of the metric (String), value (start or end entry), Negotiation ID (String), result of the negotiation (failure or success, only written for ”end” entries)

- Filename: basic_service_provisioning_time.txt
  Description: Time needed for basic service provisioning (This includes execution time and successful and failed negotiations)
  Sample entry:

  ```
  1178575207841 CSA6@Site9 basic_service_provisioning_time
      3146 success
  ```

  Column description: time stamp, name of the agent, name of the metric, time needed for allocation, failure/success

- Filename: BS_R_Mapping.txt
  Description: Mapping of service market negotiation to resource market negotiations
  Sample entry:

  ```
  1178575203777 BSA1@Site9 BS_R_Mapping Negotiation0
      Negotiation1
  ```

  Column description: time stamp, name of the agent, name of the metric, negotiation id of the service market negotiation, list of negotiation ids of the related resource negotiations

- Filename: catallactic_initial_price_range.txt
  Description: Initial price range of agent
  Sample entry:

```
1178575383665 CSA0@Site0Buyer
    catallactic_initial_price_range
    bs1 104.41305177623482 134.41305177623482
1178575383685 CSA19@Site25Buyer
    catallactic_initial_price_range
    bs1 93.78254079037917 123.78254079037917
1178575383755 RA0@Site0Seller
    catallactic_initial_price_range
    r1 112.4561961146844 142.45619611468442
```

Column description: time stamp, name of the agent and role (Buyer and seller), name of the metric, type of the requested service, initial lower limit, initial upper limit
Note: Only used in the catallactic approach

- Filename: catallactic_strategy_BSA_buyer.txt, catallactic_strategy_BSA_seller.txt, catallactic_strategy_CSA.txt, catallactic_strategy_RA.txt
  Description: Genotype, prices and internal status values of the strategy Sample entry:

  ```
  1178575229131 CSA9@Site12 catallactic_strategy_CSA
  Negotiation59 0.10000000149011612 0.6000000238418579
  0.30000001192092896 0.9990000128746033 0.5 0.0 0
  bs1 101.09558068467088 111.14513166071382
  96.14513166071382 126.14513166071382
  ```

  Column description: time stamp, name of the agent, name of the metric, negotiation id, acquisitiveness, price step, price next, satisfaction, weight memory, average profit, learning generation, product id, price, estimated market price, lower limit, upper limit
  Note: Only used in the catallactic approach

- Filename: cfps.txt
  Description: Number of received call-for-proposal messages for each seller agent.
  Sample entry:

  ```
  1178575208583 RA0@Site15 Seller cfps 5123
  ```

  Column description: time stamp, name of the agent, role, name of the metric, number of call-for-proposal messages received
  Note: Only used in the catallactic approach

- Filename: cfps_sent.txt
  Description: Sent call-for-proposal messages, one entry for each call-for-proposal message sent
  Sample entry:

```
1178488801492 CSA15@Site20 cfps_sent Negotiation0 1
```

Column description: time stamp, name of the agent, name of the metric, name of the negotiation id, number (not used)
Note: Only used in the catallactic approach

- Filename: complex_service_allocation_rate.txt
  Description: Allocation rate for each complex service
  Sample entry:

  ```
  1178498801492 CSA1@Site1 complex_service_agent_allocation_rate
      0.10183299389002037
  ```

  Column description: time stamp, name of the complex service, name of the metric, allocation rate

- Filename: complex_service_provisioning_time.txt
  Description: Sum of basic service provisioning times; This includes successful and failed allocations.
  Sample entry:

  ```
  1178488805241 CSA10@Site13 complex_service_provisioning_time
      2749 failure
  ```

  Column description: time stamp, name of the agent, name of the metric, complex service provisioning time, failure/success

- Filename: CS_BS_Mapping.txt
  Description: Mapping of complex service request to basic service negotiation id
  Sample entry:

  ```
  1178488803204 CSA10@Site13 CS_BS_Mapping
      cs1_2 Negotiation1
  ```

  Column description: time stamp, name of the agent, name, name of the metric, id of the request, related basic service negotiation id
  Note: The current central implementation does not support this metric

- Filename: csa_demand_distribution.txt
  Description: The distribution of the complex service demand
  Sample entry:

  ```
  1178488801492 CSA15@Site20 csa_demand_distribution cs1 cs1_1
  1178488802492 CSA10@Site13 csa_demand_distribution cs1 cs1_2
  ```

Column description: time stamp, name of the agent, name of the metric, type of the requested complex service, id of the complex service request

- Filename: distance.txt
  Description: The distance between the seller and buyer
  Sample entry:

  ```
  1178488803219 CSA10@Site13 BSA0@Site23 distance 2 Negotiation1
  ```

  Column description: time stamp, name of the buyer agent, name of the seller agent, name of the metric, distance, negotiation id

- Filename: latency.txt
  Description: Latency between two negotiation partners
  Sample entry:

  ```
  1178488804211 CSA14@Site17 BSA0@Site28 latency 31 Negotiation3
  ```

  Column description: time stamp, name of the buyer agent, name of the seller agent, metric name, latency, negotiation id

- Filename: market_price_resource_central.txt
  Description: Market prices for resources on the resource market
  Sample entry:

  ```
  1178748042878 RMAA0@CentralAuctioneerSite
      market_price_resource_central r1 7.692018032073975
  ```

  Column description: time stamp, site, name of the metric, resource type, price
  Note: Only used in the central case

- Filename: market_price_service_central.txt
  Description: Market prices for services on the service market
  Sample entry:

  ```
  1178748022048 SMAA0@CentralAuctioneerSite
      market_price_service_central bs1 4.70427463424487
  ```

  Column description: time stamp, site, name of the metric, service type, price
  Note: Only used in the central case

- Filename: negotiation_messages.txt
  Description: Negotiation messages sent for an accept or reject
  Sample entry:

```
1178488802297 BSA0@Site9 negotiation_messages service
    reject Negotiation0 15
1178488803219 BSA0@Site23 negotiation_messages service
    accept Negotiation1 5
```

Column description: time stamp, name of the agent which write the metric, name of metric, market, result of negotiation, negotiation id, number of messages
Note: Only used in the catallactic approach

- Filename: rejects.txt
  Description: List of rejects and the role which rejected
  Sample entry:

  ```
  1178488802297 CSA15@Site20 BSA0@Site9 rejects Negotiation0
      buyer
  ```

  Column description: time stamp, name of the buyer agent, name of the seller agent, name of the metric, negotiation id, role which rejected
  Note: Only used in the catallactic approach

- Filename: resource_allocation_time.txt
  Description: The resource provisioning time (includes the execution time)
  Sample entry:

  ```
  1178488803219 BSA0@Site23 resource_allocation_time
      start Negotiation0
  1178488804195 BSA0@Site23 resource_allocation_time
      end Negotiation0 success
  ```

  Column description: time stamp, name of the writing agent, name of the metric, event type (start or end), negotiation id, result of the negotiation (only written for ”‘end”’ events)

- Filename: resource_buyer_bid_central.txt
  Description: Bid of a basic service agent on the resource market
  Sample entry:

  ```
  36533 Site14 BSA0@Site3 resource_buyer_bid_central
      13.169972617048721 r1
  ```

  Column description: time stamp, receiver site (auctioneer), bidding agent, name of the metric, valuation (highest price to pay), resource id
  Note: Only used in the central case

- Filename: resource_seller_bid_central.txt
  Description: Bid of a resource service agent on the resource market
  Sample entry:

  ```
  11126 Site14 RA0@Site15 resource_seller_bid_central
      3.0790178353823725 r1
  ```

  Column description: time stamp, receiver site (auctioneer), bidding agent, name of the metric, reservation price (minimum price to trade), resource id
  Note: Only used in the central case

- Filename: resource_usage.txt
  Description: The resource usage, one line per "‘start"’ and "‘end"’ event.
  Sample entry:

  ```
  1178488804294 RA0@Site28 resource_usage start
      Negotiation2 {r1=1}
  1178488805282 RA0@Site28 resource_usage end
      Negotiation2 {r1=1}
  ```

  Column description: time stamp, name of the writing agent, name of the metric, event type (start or end), negotiation id, the resource bundle which was used

- Filename: service_buyer_bid_central.txt
  Description: Bid of a complex service agent on the service market
  Sample entry:

  ```
  17615 Site14 CSA7@Site23 service_buyer_bid_central
      8.995795995659913 bs1
  ```

  Column description: time stamp, receiver site (auctioneer), bidding agent, name of the metric, valuation (highest price to pay), service id
  Note: Only used in the central case

- Filename: service_seller_bid_central.txt
  Description: Bid of a basic service agent on the service market
  Sample entry:

  ```
  11136 Site14 BSA0@Site29 service_seller_bid_central
      14.11408399533697 bs1
  ```

  Column description: time stamp, receiver site (auctioneer), bidding agent, name of the metric, reservation price (minimum price to trade), service id Note: Only used in the central case

- Filename: service_usage.txt
  Description: The service usage, one line for each "‘start"’ and "‘end"’ event
  Sample entry:

  ```
  1178488804195 CSA10@Site13 BSA0@Site23 service_usage
      start Negotiation1 1
  1178488805256 CSA10@Site13 BSA0@Site23 service_usage
      end Negotiation1
  ```

  Column description: time stamp, name of the buyer, name of the seller, name of the metric, event type (Start or end), negotiation id, an integer value (deprecated)

- Filename: simulation_time.txt
  Description: The time needed for simulation
  Sample entry:

  ```
  0  NoSite simulation_time start 0
  10003325  NoSite simulation_time end 10003325
  ```

  Column description: time, site, name of metric, event type, start/end time

- Filename: successful_CS_request.txt
  Description: Successful complex service requests, one line for each complex service
  Sample entry:

  ```
  1178498801492 CSA4@Site7 successful_CS_requests 2
  1178498801492 CSA0@Site0 successful_CS_requests 21
  ```

  Column description: time stamp, name of the writing agent, name of the metric, successful cs requests

- Filename: total_cs_requests.txt
  Description: Total complex service requests received by each complex service, one line for each cs
  Sample entry:

  ```
  1178498801492 CSA4@Site7 total_CS_requests 465
  1178498801492 CSA0@Site0 total_CS_requests 507
  ```

  Column description: time stamp, name of the writing agent, name of the metric, number of cs requests

- Filename: trade_resource_central.txt
  Description: Maps basic service agents and resource service agents that trade
  Sample entry:

```
1179784806500 Negotiation29 trade_resource_central
    Negotiation0
```

Column description: time stamp, negotiation Id buyer (basic service), name of the metric, negotiation Id seller (resource service)

- Filename: trade_service_central.txt
  Description: Maps complex service agents and basic service agents that trade
  Sample entry:

  ```
  1179784817625 Negotiation81 trade_service_central
      Negotiation88
  ```

  Column description: time stamp, negotiation Id buyer (complex service), name of the metric, negotiation Id seller (basic service),

- Filename: util_satisfaction_buyer_resource_central.txt
  Description: Utility metric of a basic service on the resource market
  Sample entry:

  ```
  20983 Negotiation80 BSA0@Site9
      util_satisfaction_buyer_resource_central 0 remove
  21053 Negotiation108 BSA1@Site3
      util_satisfaction_buyer_resource_central
      0.9222974262273637 success
  ```

  Column description: time stamp, negotiation Id, name of the writing agent, name of the metric, satisfaction value, remove/success (remove if the order was withdrawn due to a time out, success otherwise)
  Note: Only used in the central case

- Filename: util_satisfaction_buyer_service_central.txt
  Description: Utility metric of a complex service on the service market
  Sample entry:

  ```
  23747 Negotiation117 CSA5@Site20
      util_satisfaction_buyer_service_central
      0.8951489201843724 success
  26071 Negotiation109 CSA8@Site24
      util_satisfaction_buyer_service_central 0 remove
  ```

  Column description: time stamp, negotiation Id, name of the writing agent, name of the metric, satisfaction value, remove/success (remove if the order was withdrawn due to a time out, success otherwise)
  Note: Only used in the central case

- Filename: util_satisfaction_resource_buyer_decentral.txt
  Description: Resource buyer's utility
  Sample entry:

  ```
  1178488804195 BSA0@Site23
      util_satisfaction_resource_buyer_decentral
      Negotiation1 0.21748918596452227
  1178488805317 BSA0@Site28
      util_satisfaction_resource_buyer_decentral
      Negotiation3 0.0013210052001667583
  ```

  Column description: time stamp, name of the writing agent, name of the metric, negotiation id, utility
  Note: Only used in the catallactic approach

- Filename: util_satisfaction_resource_seller_decentral.txt
  Description: Resource seller's utility
  Sample entry:

  ```
  1178488808659 RA0@Site28
      util_satisfaction_resource_seller_decentral
      Negotiation9 0.10714285524219869
  1178488810254 RA0@Site11
      util_satisfaction_resource_seller_decentral
      Negotiation11 0.0795453827887711
  ```

  Column description: time stamp, name of the writing agent, name of the metric, negotiation id, utility Note: Only used in the catallactic approach

- Filename: util_satisfaction_seller_resource_central.txt
  Description: Utility metric of a resource service on the resource market
  Sample entry:

  ```
  20983 Negotiation85 RA0@Site3
      util_satisfaction_seller_resource_central
      0 remove
  21053 Negotiation112 RA0@Site3
      util_satisfaction_seller_resource_central
      0.08424893267942524 success
  ```

  Column description: time stamp, negotiation Id, name of the writing agent, name of the metric, satisfaction value, remove—success (remove if the order was withdrawn due to a time out, success otherwise)
  Note: Only used in the central case

- Filename: util_satisfaction_seller_service_central.txt
  Description: Utility metric of a basic service on the resource market
  Sample entry:

  ```
  26071 Negotiation111 BSA0@Site3
      util_satisfaction_seller_service_central
      0 remove
  26842 Negotiation135 CSA1@Site8
      util_satisfaction_seller_service_central
      0.8700211740132909 success
  ```

  Column description: time stamp, negotiation Id, name of the writing agent, name of the metric, satisfaction value, remove—success (remove if the order was withdrawn due to a time out, success otherwise)
  Note: Only used in the central case

- Filename: util_satisfaction_service_buyer_decentral.txt
  Description: Service buyer's utility
  Sample entry:

  ```
  1178488804234 CSA14@Site17
      util_satisfaction_service_buyer_decentral
      Negotiation3 0.19718347083943188
  1178488807691
      CSA6@Site9 util_satisfaction_service_buyer_decentral
      Negotiation7 0.07608043102226603
  ```

  Column description: time stamp, name of the writing agent, name of the metric, negotiation id, utility
  Note: Only used in the catallactic approach

- Filename: util_satisfaction_service_seller_decentral.txt
  Description: Service seller's utility
  Sample entry:

  ```
  1178488803219 BSA0@Site23
      util_satisfaction_service_seller_decentral
      Negotiation1 0.0
  1178488804211 BSA0@Site28
      util_satisfaction_service_seller_decentral
      Negotiation3 0.1668412999533775
  ```

  Column description: time stamp, name of the writing agent, name of the metric, negotiation id, utility
  Note: Only used in the catallactic approach

Chapter 3

Guide to conducting simulations

This chapter describes first how to install and run the CATNETS scenario generators and simulator and then how to set the various parameters of the simulation.

3.1 Installation and Running

These instructions describe how to install and run CATNETS scenario generators and the CATNETS simulator. Three ZIP files of the needed packages can be downloaded from the CATNETS web site:

`http://www.catnets.org/download/`

The first ZIP file, called `catnets-manual-scenario-generator.zip` includes the source code, the the generated class files, and the javadoc documentation of the manual scenario generator. The second ZIP file, called `catnets-automated-scenario-generator.zip` includes the source code, the generated class files, and the javadoc documentation of the automated scenario generator. The third ZIP file, called `catnets-simulator.zip` includes the source code, the generated class files, the javadoc documentation and usage examples of the simulator.

3.1.1 Software Dependencies

- Java(TM) 2 Platform Standard Edition Development Kit 5.0 or greater
- Ant: Version 1.6.5 or greater (to re-build the code after any changes or to run functional tests)

3.1.2 CATNETS manual scenario generator

Installing

1. Start by unpacking the code from the ZIP file by using an archiving package such as `WinZip` (do not open the file directly from the browser but save it to disk first and then open it).
2. Go down into the `catnets-manual-scenario-generator` directory.

   `catnets-manual-scenario-generator` is now ready to run!

Running

- The main executable is called `catnets-msg.bat` and can be found in the main `catnets-manual-scenario-generator` directory.
- When running `catnets-msg` the user must have write permission to the current directory so `catnets-msg` can write output files.
- `catnets-msg` is run from the command line and takes zero arguments

  Usage:

  ```
  $ catnets-msg.bat$
  ```

- The usage of the manual scenario generator is explained in D2.1 [WP206], Section 3.

3.1.3 CATNETS automated scenario generator

Installing

1. Start by unpacking the code from the ZIP file by using an archiving package such as `WinZip` (do not open the file directly from the browser but save it to disk first and then open it).
2. Go down into the `catnets-automated-scenario-generator` directory.

   `catnets-automated-scenario-generator` is now ready to run!

Running

- The main executable is called `catnets-asg.bat` and can be found in the main `catnets-manual-scenario-generator` directory.
- When running `catnets-asg` the user must have write permission to the current directory so `catnets-asg` can write output files.
- `catnets-asg` is run from the command line and takes zero arguments

  Usage:

  ```
  $ catnets-msg.bat$
  ```

- The usage of the automated scenario generator is explained in Section 2.1.

3.1.4 CATNETS simulator

Installing

1. Start by unpacking the code from the ZIP file by using an archiving package such as `WinZip` (do not open the file directly from the browser but save it to disk first and then open it).
2. Go down into the `catnets-sim` directory.

   `catnets-sim` is now ready to run!

Running

- The main executable is called `catnets-sim.bat` and can be found in the main `catnets-simulator` directory.
- When running `catnets-sim` the user must have write permission to the current directory so `catnets-sim` can write output files.
- `catnets-sim` is run from the command line and takes either zero or one arguments. The optional argument is the parameters file (explained in the next section), and if no file is specified the default parameters file located at `examples/parameters_catnets.conf` is used.

  Usage:

  ```
  $ catnets-sim.bat [parameters file]$
  ```

3.2 CATNETS simulator parameter file

The parameter file for the CATNETS simulator had already been partially described in Deliverable D2.2 [WP206]. For the sake of clarity, the full description of the parameter file is given here again.

The simulation parameters are set manually by the user in a parameters file. The default parameters file is `examples/parameters_catnets.conf`. Following is an explanation of each parameter.

3.2.1 General Parameters

aln.topology.file - The configuration file to describe the ALN topology.

aln.bs.file - The configuration file to describe the basic services.

aln.arb.file - The configuration file to describe the available resource bundles.

cs.configuration.file - The configuration file to describe the complex services.

number.complexservices - The number of CSs submitted during the simulation run.

users - Determines the pattern in which ALN users submit CSs to the Complex Service Dispatcher. Options:

1. **Simple:** submit CSs at regular intervals until all CSs have been submitted. The interval is set by the **cs.delay** parameter (below).
2. **Random:** submit CSs at intervals which are uniformly random between zero and twice the **cs.delay**.

policy - Determines the scheduling policy of the Complex Service Dispatcher. Options:

1. **Random:** CSs are scheduled randomly to any CSA that will run the CS.
2. **Queue Length:** schedules to the CSA with the shortest queue of waiting CSs. If two CSAs have the same shortest queue length one of them is chosen at random.

cs.delay - The basic time interval (in milliseconds) between CSs being submitted to the ALN by the Users during simulation. The actual submission interval depends on the type of user chosen (see above).

access.pattern.generator - Determines the order in which BSs are accessed within a CS. Options:

1. **SequentialAccessGenerator:** CSs are accessed in the order stated in the CS configuration file.

2. **RandomAccessGenerator:** CSs are accessed using a uniform random distribution;
3. **RandomWalkUnitaryAccessGenerator:** CSs are accessed using a unitary random walk, starting from a CS chosen using a uniform random distribution.
4. **RandomWalkGaussianAccessGenerator:** CSs are accessed using a Gaussian random walk, starting from a CS chosen using a uniform random distribution.

random.seed - Determines whether the seed used by various methods within the CATNETS simulator where random numbers are required is fixed or random. If this is set to `yes`, it will be random; if `no`, it will be fixed. For example, if it is `yes`, a different set of CSs will run each time the simulation is run. If it is `no`, the same CSs will run each time.

max.queue.size - The maximum number of CSs the CSA will hold in its queue before it refuses to accept any more.

bs.execution.time - The time in milliseconds for a CSA to execute each BS.

3.2.2 Central Market Parameters

The parameters for the auctioneers are stored in the properties file `market_central.properties`. In the following, the semantics of each parameter is briefly discussed.

Basic Service Agent Parameters

These parameters affect the behavior of a basic service agent.

basic.useServiceMarketPrice Defines the pricing model to be used

- basic.useServiceMarketPrice = 1: Use the price on the service market as a maximum bid for the resource market (e.g. bought ServiceA for 10, bid at most 10 on the resource market).
- basic.useServiceMarketPrice = 0: Draw the valuation for the resource market from an independent distribution.

Service Market Parameters

These parameters affect the behavior of a service market auctioneer.

service.kprice $k \in (0..1)$ value for the k-pricing schema on the service market. Set this to 0.5 in most cases.

Resource Market Parameters

The following parameters affect the behavior of a resource market auctioneer.

resource.kprice $k \in (0..1)$ value for the k-pricing schema on the resource market. Set this to 0.5 in most cases.

resource.numberattributes The number of attributes each resource has

resource.updateunsuccessful Defines if valuation and reservation prices should be updated

- resource.updateunsuccessful=0: Valuation/Reservation of unsuccessful agents are not changed after each clearing period
- resource.updateunsuccessful=1: The Valuation/reservation price of unsuccessful agents should be updated after each clearing period

resource.orderbook.finddisjunctivesets A boolean value that defines if the optimization engine should search for disjunctive order sets on the resource market.

resource.orderbook.split This is a fixed value which has to be 0.

resource.allocator.model This is a fixed value which has to be 3.

resource.allocator.solver Determines the external solver to be used

- resource.allocator.solver=0: Use CPLEX to solve the winner determination problem on the resource market
- resource.allocator.solver=1: Use LPSolve to solve the winner determination problem on the resource market

resource.allocator.timelimit Time-Out (integer value in ms) for the solver

Valuation Generator Parameters

The following parameters affect the behavior of the valuation generator.

valuation.imitateStrategy See Section 2.3 for details.

valuation.smallestvalue Defines the smallest value for a valuation or reservation price (try to avoid zero values).

- valuation.imitateStrategy=0: Use a normal distribution for generating valuations and reservation prices
- valuation.imitateStrategy=1: Imitate the decentral strategy

- if valuation.imitateStrategy = 0

  valuation.normal.mean Mean of the normal distribution

  valuation.normal.deviation Standard deviation of the normal distribution

- if valuation.imitateStrategy = 1

  valuation.strategy.markepriceweight Weight of the current market price

  valuation.strategy.coldstartvaluation Value that is returned if there are no market prices or valuations in the queue (cold start problem)

  valuation.strategy.normalmutationmean Mean of the normal distribution to imitate mutation

  valuation.strategy.normalmutationdeviation Standard deviation of the normal distribution to imitate mutation

  valuation.strategy.normalpricestepmean Mean for the price step distribution

  valuation.strategy.normalpricestepdeviation Standard deviation for the price step distribution

  valuation.strategy.depthweightedaverage Depth of the weighted average (maximum age of the historical price information)

  valuation.strategy.buyersellermultiplier Scaling factor for the generated valuations and reservation prices

3.2.3 Market Parameters

The following parameters are specific for the service/resource allocation mechanisms.

market.model - Set to `1` to use the catallactic allocation mechanism or `2` to use the centralised mechanism.

market.decentral.file - Configuration file including parameters for the catallactic market (see Section **??** for detatils).

price.range.randomize - Randomize initial price range of the agents. This parameters gives the possibility to randomize the initial price ranges of the catallactic market configuration. A value of 0 means change of the initial price range.

market.connect - Connect the prices of the service market and resource market. If value is `yes`, the basic service seller's outcome is the budget of the basic service buyer on the resource market.

resource.model - Resource model selection (resource); values: `shared`, `dedicated`. The catallactic strategy implementation is able to handle different resource models. In the `shared` resource model, the resource provider can allocate different resource bundles to different basic services. The `dedicated` resource model allocates the whole resources exclusively to one basic service.

cfp.selection.model - How to select proposals: `0` fifo - one shot; `2` best price - one shot. The `fifo` selection model takes the fastest received proposal and starts the negotiation, whereas the `best price` policy ranks all received proposals and selects the cheapest one for negotiation.

max.coallocation - Maximum number of co-allocated resources. This property defines the number of different resource providers a basic service is allowed to allocate.

market.central.service.clear - Clearing policy for the centralised service market: `1` Call Market or `2` Continuous.

market.central.service.clearinterval - Call market clearing interval for the centralised service market; defines after how many ms the market will be cleared.

market.central.resource.clear - Clearing policy for the centralised Resource Market: `1` Call Market or `2` Continuous

market.central.resource.clearinterval - Call market clearing interval for the centralised resource market; defines after how many ms the market will be cleared.

3.2.4 Negotiation Parameters

The following parameters regulate how negotiations are conducted in both the catallactic and centralised mechanisms.

cfp_ann.hop.count - Regulates the propagation of cfps or announce messages over the network when the catallactic mechanisms is adopted.

learning.hop.count - Regulates the propagation of learning messages over the network when the catallactic mechanisms is adopted.

discovery.timeout - Time in milliseconds agents wait for proposal after they've sent cfps.

timeout - Time in milliseconds agents wait for non-blocking reception of messages during negotiations for services or resources.

message.size - Size of messages (in Kbytes) - size = 0 implies instantaneous message delivery.

3.2.5 Other parameters

time.advance - Use advanced grid time (`yes`) or not (`no`) (see Section 2.2 for details).

time.of.day - The time of day used as starting point. Should be in hours, with minutes after the decimal point e.g. 22.5 for 22:30, and must be on the hour or half-hour.

metrics.path - The path where files recording metrics collected during simulations are stored.

3.3 Simulation output

Every simulator run produces the set of technical metrics described in Section2.5. One file is generated for every metric, the file name being `<metric_name>.txt`. All the files produced by a run are stores in a newly created directory, whose name is the result of the Java call `System.currentTimeMillis()` which returns the current absolute time in milliseconds.

Chapter 4

Conclusions

4.1 Achieved results

The CATNETS simulation environment poses low requirements on simulation run. Implemented in pure JAVA, the CATNETS simulator runs on all machines which are supported by the Java Runtime Environment. This enables small scale simulation on desktop machines and large scale simulation on multi-core 32 and 64 bit server machines. The pure JAVA implementation gives the possibility of easy adoption of the current code to new simulation scenarios of application layer networks in utility computing or autonomic computing areas.

The high resource and service abstraction and the two-tiered market implementation supports various areas of application. The introduction of resource bundles enables the modeling of not only a specific resource type like data resources, but complex resource products for future peer-to-peer enabled Grid applications. We assume, visualization techniques and local resource managers are in place and offer an abstract resource bundle to services. In CATNETS, we implemented two different allocation policies for these resource bundle, a centralized auctioneer using a multi-attributive combinatorial auction and the catallactic approach using bilateral bargaining.

A resource provider can select between two implemented resource models for his resource service, a shared and a dedicated resource model. Using the dedicated resource model, super computing or autonomic computing can be simulated, whereas the shared resource model represents scenarios of the utility computing field. Both resource models allow co-allocation of resource bundles from different resource providers. This allows the simulations of basic services with high resource demands like the execution of batch jobs in the super computing area. Not all possible co-allocation scenarios are supported by the current catallactic implementation because of its high complexity. In the catallactic approach, we assume the co-allocated resources have the same resource bundle size, capacity and product id. The central approach supports all co-allocation combinations which allows allocation of bundles with different size and capacity.

The service market decouples the service requests from the resource market. A complex service doesn't have to know how many resources there are and how many resources he needs for his service. The complex service can focus on creating value added services to the user. Currently, the complex service sequentially request a list of basic service. This could be enhanced in future releases of the CATNETS simulator with more sophisticated workflow engines. As on the resource market, an service allocation policy is applied to allocate services. In CATNETS, we implemented two allocation approaches, a continuous double auction and the catallactic bargaining.

Supporting both allocation mechanisms, the simulator provides proactive and reactive interfaces for software agents. Proactive agents act on their own. They periodically check, if there is new demand or supply and send their bids to the auctioneer. In the reactive agent model, the agents wait for new events like incoming messages before they act on new situations.

The simulator provides a rich messaging model including a large set of different message types, a P2P messaging layer with flooding, load-link dependent message delay, and a simple message failure model. This enables the simulation of real life influences on the resource allocation approaches. Interfaces ease the implementation of an improved P2P layer or new message types.

Various tools were developed to support the configuration of the simulator. Scenario generators help to create new scenarios or configure the catallactic market. The simulator supports plain text file based configuration. This allows fast reconfiguration of the scenarios between simulations runs.

A large set of metrics was implemented in the simulator. This set of metrics helps to debug and evaluate the simulation runs. Technical and economic metrics are written into text files which are evaluated with MATLAB scripts ex-post. Again, the use of text files gives the possibility to use any tool for analysis.

The simulation environment and all developed tools will be released under an open source licence. This will give other researchers the possibility to modify and extend the simulator for their own research.

4.2 Current Limitations

The simulator and its current implementation of the CATNETS scenario have some limitations. These limitations result from assumptions made to reduce the implementation complexity.

Currently, the allocation approaches don't support parallel negotiations. Seller and buyers can negotiate with only one other negotiation partner at the same time. In CATNETS, we abstracted from internal behaviour of the agents using random number generators. We adapted here a common process used in simulation as a research method. For commercial use, a more detailed decision model has to implemented which fits exactly to the given environment.

The advanced Grid time model of the CATNETS simulator is limited to the catallactic allocation approach. This leads to long running simulations of scenarios of the central allocation approach compared to the catallactic case. More person months than originally planned were needed to fix bugs of the simulator code. Therefore, this feature could not be implemented.

The same reason holds for the support of co-allocation and the shared resource model. Both are supported only with limitations in the catallactic model.

Large simulations consume lots of memory. Therefore, these simulations should be executed only on servers with at least 2GB of main memory.

4.3 Future Extensions

The simulations environment will be used and extended in the EU project eRep. Reputation will be added to the simulation scenario. The implementation model of the agent will be replaced by BDI agents and electronic institutions will be introduced. For more information, the reader is referred to the eRep web site: http://megatron.iiia.csic.es/eRep/.

Furthermore, the failure model if the sites, resources and service will be extended and risk management techniques will be introduced. This will enable the simulation of different quality of service levels on the resource and service market.

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