Comparing Multicast and Newscast Communication in Evolving Agent Societies

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ABSTRACT

This paper investigates the effects of two different communication protocols within an artificial society, where communication and co-operation is necessary to survive. Communication in our system is not a hard-coded behavior, rather it is an evolvable feature. The two protocols we consider differ significantly. Using the first approach, individuals multicast messages that can be received by any individual. In the second approach, based on the so-called newscast computing model, individuals send a message to their list of ”friends” only, where this list is frequently updated. These protocols are compared experimentally by their effects on population dynamics and the evolution of communicativeness. The results provide new insights into the niche of newscast-based communication protocols: we identify two essential processes (information being spread and information loosing its value) and consider the ratio of the speeds of these processes as a basic indicator for communication success.

Categories and Subject Descriptors

H.1 [**Information Systems Models and Principles**]: Systems and Information Theory—*Value of Information*

General Terms

Experimentation, Theory

1. INTRODUCTION

The newscast information exchange protocol has been invented during the DREAM project[1] for distributed evolutionary computing frameworks and evolving agent societies have been described as an application area. The goal of this study is to present a working implementation and an experimental assessment of this protocol in this application area, shading light on particular features of newscast based communication and to identify the circumstances where such protocols offer advantages.

The first technical research objective of this paper is to compare the effects of two drastically different communication protocols on artificial agent societies using these protocols. The second technical objective of this paper is to investigate the evolution of communicativeness. We experiment with artificial societies in SugarScape-like worlds that are set up in such a way that cooperation is required for survival and communication is an evolvable feature that facilitates cooperation. Our experiments are carried out using the JAWAS system, version 1.2.3 [2] that was designed for experimentation, data collection, and visualisation for studying artificial societies.

As for the first objective, we compare protocols based on multicast and newscast. In the multicasting setup, individuals send messages that can be received by any individual. Technically, this method was implemented through a message board where senders can put their messages and any individual can read the present content of this message board [2]. The research presented in this paper includes a novel, decentralised communication method where information is transferred directly between agents without a third party (message board, or alike). The basis of this communication mechanism is the newscast method [6, 7]. Technically all agents maintain a list of other agents (or rather, addresses or identifiers of other agents) and send their messages to all agents on this list and no-one else. It is an essential feature of the method that agents frequently update their “lists of friends”, leading to a dynamically changing communication network.

Considering the second technical objective, we provide the *possibility* to communicate, but do not enforce communication on the agent population. Instead, we make the affinity, or willingness, to communicate an evolvable feature and monitor its development. This objective is orthogonal to the first one mentioned above. It is interesting to mention that our approach is complementary to some of the classics. Namely, we study the emergence of communication under fixed properties of cooperation (hard-coding its mechanics), while many studies focus on the emergence of cooperation under fixed properties of communication, see for instance [1] (that assumes there is none).

The contribution of the work presented here is threefold. Firstly, we adopt the general newscast protocol in an artificial society context (and provide access to the software implementing it). Secondly, we introduce agents whose willingness to communicate is an evolvable feature. Thirdly, we conduct experiments and analyse experimental data concerning numerous observables. Our results show that communication emerges through evolutionary learning within the agent populations regardless the applied communication protocol.

Furthermore, the outcomes provide insight about the niche of newscast based communication protocols. This insight is based

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on the identification of two essential processes (information being spread and information loosing its value) and considering the ratio of the speeds of these processes as a basic indicator. From observations and a preliminary analysis we conclude that in the investigated worlds it may not be the (de)centralized nature of a communication protocol that determines its success, but rather a feature from the world itself.

This paper is organised as follows. Section 2 explains the realisation of cooperation and communication in our artificial society. Section 3 explains the VUSCAPE world. In Section 4, we give a brief overview of the experimental settings of our empirical investigation and analyse our empirical findings. Section 5 analyses the observed dependency between information value decay and dissemination rates. Finally, Section 6 concludes and contains pointers for future work.

2. ARTIFICIAL SOCIETIES

The area of research concerning the investigation described in this paper involves the combination of cooperation and communication in artificial societies. We researched an artificial society in VUSCAPE [2], based on the SUGARSCAPE world [5]. This artificial society concerns a two dimensional grid, wrapped around the edges, where each position corresponds with an area which can contain multiple agents and some amount of sugar. Agents move through the world by vertically or horizontally jumping to another location (cf. moving in SUGARSCAPE). The agents live off the sugar, determining their level of fitness. The need for agents to communicate with each other arises from the requirement to cooperate in order to survive [8, 9]. Cooperation is enforced upon the agents by limiting the amount of sugar that they can eat by themselves.

2.1 Cooperation

Cooperation means that the agents together consume the sugar at the location. It is imposed on agents as they need to eat sugar in order to survive, combined with their incapability to consume large quantities of sugar on their own. For the combination of these two, agents need to work together to live their maximum age. For two (or more) agents to successfully cooperate, they have to be on the same location and the amount of sugar at that location must exceed the maximum amount an agent can eat individually. After cooperation, the amount of sugar is divided equally among the agents.

Each agent can harvest a maximum amount of sugar on its own. This amount is called the *cooperation threshold*. If an agent is at a location at which the amount of sugar is over this threshold, it needs other agents to harvest the sugar. If there are more agents at such a location, these agents harvest the sugar together and the sugar is evenly distributed over these agents. In the empirical investigations described below, the cooperation threshold is the same for all agents on all positions at all times.

2.2 Communication

In our artificial society, agents are endowed with talk and listen capabilities, which are evolvable. Both talking and listening are evolving features as they undergo variation and selection. The talk feature determines whether the agent performs a communicative action itself, namely informing other agents of: 1) the amount of sugar that is on its location, and 2) the coordinates of its location. The listen feature is used in the observation and decision making processes of the agent. By listening, the agent receives information from other agents about amounts of sugar at the locations of those agents.

After initialisation, the average talk preference and listen preference over all agents is 0.5. With a preference p, an agent communicates the amount of sugar at its location with probability p in case it needs help to harvest the sugar at its location. With a listen preference q the agent takes up received information from other agents in its decision process on where to move to; with probability $1-q$ the agent does not consider received information from other agents.

Multicast Model Communication between agents in the first series of experiments described here, is implemented by means of multicasting. Multicasted messages from agents travel only over the axes and are not heard in the whole world. The rationale behind this is based on the fact that our agents can only move horizontally or vertically but not diagonally. The agents thus only receive messages from locations to which they can jump to immediately.

The multicast communication is implemented by a centralised message board. Agents can post their messages to this board (talking) and they can read out messages from this board (listening). A message is removed from the message board when an agent reads it. The practical implementation is thus slightly different from the way how agents would conceptually communicate.

Newscast Model The newscast computing model is a fully distributed information propagation protocol for large-scale peer-to-peer computing [6, 7]. The main idea of newscast is that each agent maintains a cache of information items holding the information for and from the agent; the cache also contains the names of all agents that are "friends" with the agent. The cache of names, i.e., IDs and addresses, is used each time a communication is initiated by the agent. Each agent can listen and receive the messages from other agents that have it in their cache. At fixed time intervals, the agent updates the information in its cache and the list of names.

Each agent has a *correspondent module* that maintains a cache of $c > 0$ newsitems, where c is fixed. A news item contains a timestamp, the agent ID and the message itself (location + sugar amount). Agents regularly exchange their caches by following this procedure (where the local agent is the agent who initiates an exchange with a peer agent):

1. Request a fresh news item from the local agent and merge the item into the cache.
2. Randomly select a peer correspondent by considering its ID as found in the cache.
3. Send and receive each other's caches. Merge received items into the local cache.
4. Since the cache now contains $2c+1$ cache items, the oldest ones are thrown away to keep the c freshest ones (breaking ties randomly).

3. THE VUSCAPE MODEL

The technical basis of our experimental work is the JAWAS platform, where JAWAS stands for Java-based Artificial Worlds And Societies. The artificial world used in this paper is VUSCAPE, inherently based on the well known SUGARSCAPE world, as introduced by Epstein and Axtel [5] as a generic testbed for social simulation. For the purpose of the study described in this paper, we extended the SUGARSCAPE world in a number of ways, thereby introducing the possibility to research the specific emergent phenomena of our interest. Additionally, these adaptations extend the SUGARSCAPE domain in an interesting generic way, opening up possibilities to investigate SUGARSCAPE worlds in wider perspectives.

Like SUGARSCAPE, the VUSCAPE world is a two dimensional grid, wrapped around the edges. Each position corresponds with an area which can contain multiple agents and an amount of sugar. Sugar grows from sugar seeds; each seed has a maximum amount of sugar to which it can grow. VUSCAPE and SUGARSCAPE differ with respect to some changes we made concerning cooperation, communication, explorative behaviour, increased grid-point inhabitance, randomised sugar distribution, and randomised age initialisation. The effects of these changes were investigated experimentally in [3].

3.1 Model Description

The VUSCAPE world evolves with discrete time steps, called cycles. In one such an execution cycle, the world (including agents) is updated. More precisely, the following stages take place in chronological order within a single execution cycle. During a single cycle, all stages are executed for each agent in parallel. In Figure 1, the agent control loop as described below is shown.

1. An agent *gathers information* about the presence of sugar in the world. This is done by means of listening (from other agents along the axes) and looking (by looking at the directly surrounding locations along the axes and the current location). Upon completion of this stage, the agent has at its disposal an array of locations and amounts of sugar on these locations.

2. Based on this array, the agent picks out the location with most sugar and *moves* to this location. In case there are multiple locations with the most amount of sugar, the agent chooses a random one from these locations and moves there.

3. Having arrived at the sugar, this sugar is *harvested* in case the amount is under the cooperation threshold. If the amount is above the cooperation threshold, the agent cooperates immediately if there are more agents at the location. Otherwise, it *communicates* (with some probability) to the other agents among the same axes that it needs help.

4. If possible, the agent *reproduces* and generates offspring. For this, it is (at least) necessary that there is another agent of the opposite sex at the location. Offspring is generated by applying discrete recombination on the talk an listen genes, where the richest parent donates the allele for the child. Thereafter Gaussian mutation is applied to the child with $\sigma = 0.1$.

3.2 Model Formalisation

Let a world state $s \in S$ consist of a set of sets of agents A and resources R. Thus $S = A \times R$. Each agent $a \in A$ is indexed by a time $t \in T$, and identifier $i \in I$, and parameterised by its energy $e \in \mathbb{R}$, location $n \in N$ (where N would normally be $\mathbb{N} \times \mathbb{N}$ denoting horizontal and vertical position), vision $v \in \mathbb{N}$, metabolism $m \in [0,1]$, etcetera. Formally, $a_t^i \in A = \mathbb{R} \times N \times \mathbb{N} \times [0,1]$. For example, agent number 3 at time 5 has energy level 34, is at location (2,0), has vision 3, etcetera is denoted by $a_5^3[34,(2,0),3,\ldots]$. Every resource $r \in R$ is also indexed by time and identifier, and parameterised by nutrition value, reward, mobility and regrowth rate, which are all integers. The nutrition value denotes the increase in energy that an agent receives when it consumes the resource. The reward can be considered a (monetary) payment received when the resource is collected. The mobility denotes the rate at which the resource moves through the world (e.g., a tree does not move, whereas a prey may move very fast). Finally, the regrowth rate is the rate at which a resource grows back. Formally, $r_t^i \in R = \mathbb{N} \times \mathbb{N} \times [0,1] \times [0,1]$. For example, the resource $r_9^8[10,5,0.2,0.8]$ is a nutricious and rewarding resource, that is not very mobile but grows back quickly.

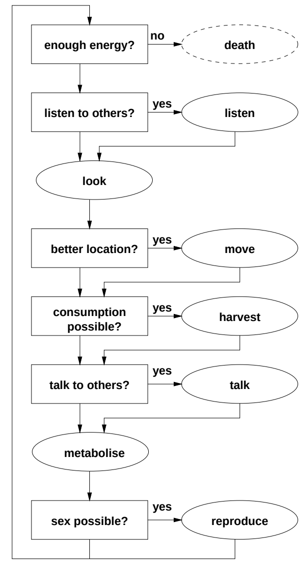


Figure 1: The agent control loop in VUSCAPE**.**

The descriptions of the agents and resources together make up a state description. We define a transition function $\tau : s_t \rightarrow s_{t+1}$ over these states, which describes the state dynamics over time. This function is composed of a number of functions related to agents and resources. Agents have functions concerning move, harvest, look, listen and talk actions; resources have regrow and move functions.

The specifications of the talk and listen functions much depend on the used communication protocol (either multicast or newscast in this paper). Such protocol defines a connectivity graph for information exchange between agents. The shape of this graph majorly determines the success of the agent society. We demonstrate this effect by empirical analysis below.

4. EXPERIMENTS

We have conducted two series of experiments, each consisting of 10 independent runs: one experiment with centralised (multicast) communication and another with decentralised (newscast) communication[2]. Although 10 runs may seem too few, Figure 2 shows such a degree of consistency between the runs that we considered 10 enough. In both experiments, the cooperation threshold is 1. The lifetime of the world is 2,000 iterations. The height and width of the world are both 50. The initial population contains 1,000 agents. All sugar is redistributed every iteration. Talk and listen features are inherited from the parent with the most sugar. Further details can be found in [4].

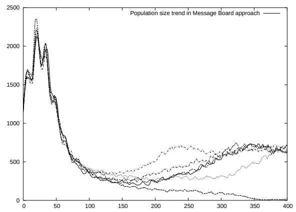
We practically monitor all experimental variables (as this is easily possible with the VUSCAPE software), but we are particularly interested in the population size, talk and listen preference, number of in-need-of-help situations and number of cooperations. For reasons of space, we have not included all graphs.

4.1 Results

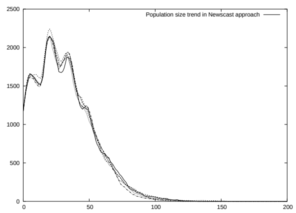
This Section presents the results of our empirical investigation and some preliminary analysis. We present results for two different

[2]Additionally, we conducted a benchmark experiment in which there was no communication [4]. We have not included the results of this experiment here for reasons of space.

POPULATION SIZE



MULTICAST



NEWSCAST

Figure 2: Graphs for development of population size for multicast and newscast communication.

Measurement	Multicast	Newscast
Listening success ratio	91%	54-57%
Uninformed movement ratio	77%	57-60%
Starvation ratio	97-100%	97-100%
Nothing heard ratio	79%	97%
Nothing saw ratio	82% of the cases they do not see anything good	83% of the cases they do not see anything good
Old population ratio	from 32% of the total population to 0.3-0.5% at iteration 65	from 25% of the total population to 1%
Talk and wait ratio	4.7-5%	28.5%
Success in talk and wait ratio	67.5-68%	25%
Average sugarAmount per agent	The trend is descendant to 3.5-5 units	The trend is descendant to 4 units
InNeedOfHelp	about 25%	about 37% to iteration 36 up to 57% to iteration 72
ExploreCell	about 75%	about 55-57%
HasEaten	about 55-60%	about 43% to iteration 36 45-50% to iteration 55-60 and then zero
Cooperation	20-22%	7.5-12.3% to iteration 36 up to 15% to iteration 62-70

Table 1: Empirical results for centralised (multicast) and decentralised (newscast) communication

experimental settings, i.e., for multicast and newscast communication, respectively. The obtained results have been included in Figure 2, Table 1 and on the last page. The graphs show the outcomes of 10 independent runs overlaid. The measurements used in Table 1 mean the following:

- *Listening success ratio* – number of successfully ended listenings (actually finding the heard sugar amount upon arrival) divided by the total number of “worthy” listenings (movement after listening).
- *Uninformed movement ratio* – number of uninformed movements (move to another location without any information) divided by the total number of movements.
- *starvation ratio* – number of agents that died of starvation (lack of food) divided by the total number of deaths in the world. (Others die of old age.)
- *nothing heard ratio* – number of agents that have listened, but not hear any non-zero amount value divided by the total number of agents that have listened.
- *nothing saw ratio* – number of agents that have looked around as much as their vision allowed but did not see any sugar pile divided by the total number of agents that have looked for sugar in the same iteration.
- *old population ratio* – number of agents older than the maximum age for reproduction divided by the total number of agents in the current iteration.
- *talk and wait ratio* – cases of talk and wait at a position divided by the total number of talks about non-zero values.
- *success in talk and wait ratio* – cases of talk and wait that will end up with a successful eating divided by the total cases of talk and wait.
- *average sugaramount percentage* – sugar average at the population level.
- *in need of help* – percentage of agents that are in need of help in the current iteration.
- *explore cell* – percentage of agents that visited a cell they had not been yet.
- *has eaten* – percentage of agents that has eaten during the current iteration.
- *cooperation* – percentage of cooperations, with respect to the total population size, during the current iteration.

4.2 Analysis

The most important trend that we observe in our data graphs is that populations using newscast communication die out, while the multicast populations do not: newscast communication is less effective in the VUSCAPE world than multicast, i.e., it does not provide sufficient information that is helpful for the agents. Instead, the newscast communication allows, unintentionally, the propagation of timed out messages. In the case of these ’‘lies”, agents listen to messages, move to the heard location, and find the food already eaten. The listening success rate (food is still there on arrival) is about 57% of the cases; for multicast communication, around 91% of the cases the agents listen to a message, move to the listened location, and successfully eat food. We hypothesise that the lies emerge with newscast communication because of the very structure and characteristics of the protocol: it cannot prevent spreading of outdated information. Because of this outdating, agents may jump to an announced location where the sugar was consumed by a earlier listener.

As for the second technical objective, our results show that communication emerges through evolutionary learning within the agent populations regardless the applied communication protocol. With this respect there is no difference between multicasting and newscasting, even the pace of development seems to coincide. (NB, mind the different time scales on the x-axes of the corresponding graphs.)

To shed light on possible reasons why the newscast populations die out, we have considered other monitored parameters that were not directly related to the research objectives. Therefore we added two more monitors, namely in-need-of-help and cooperation. The *in-need-of-help* monitor measures the number of agents that cannot eat or harvest at the location where they are because there is too much sugar (amount > cooperation threshold) with respect to the total number of agents. The *cooperation* monitor measures the number of agents that cooperate with respect to the total number of agents.

We analyse the data up to the moment that the newscast population starts dying out (at approximately iteration 100). For the iterations up till 100, the average in-need-of-help value for newscast (growing towards 0.6) is substantially higher that for multicast (stabilising at around 0.3). For these iterations, we also observe that the average cooperation value for newscast (growing towards 0.15 then decreasing to 0.10) is lower than for multicast (growing towards 0.20).

These observations that newscast populations are in more need of help and carry out less cooperation acts, indicate that newscast populations are less clustered than the multicast populations. The communication protocol plays a crucial role in the clustering of populations. If agents are able to communicate effectively, this has a positive effect on the degree of clustering. The main reason for this is that agents communicate in order to come together in order to collectively consume large amounts of resources. This directly results in agents consuming more resources, hence higher survivial chances. Moreover, an important side effect is that agents reproduce more often. A requirement for reproduction is that two agents are at the same location and the chance that this happens increases in populations with a high clustering degree. In summary, the measured values of in-need-of-help and cooperation imply that newscast populations thus die out because the agents cannot consume sufficient resources to survive, added with the side-effect that they have fewer opportunities for reproduction, hence fewer offspring.

5. INFORMATION DISSEMINATION VERSUS VALUE

Our empirical findings point to the hypothesis that there is a strong relation between the dissemination of information and the speed at which information loses its value. In the VUSCAPE world, we define these concepts as follows:

- dissemination of information σ: average number of iterations it takes for all agents to receive particular information about a quantity of sugar at some location,
- value of information υ: average number of iterations after which sugar at some location heard of has not yet been been consumed.

5.1 Dissemination of information

Let us assume a connected directed graph $G = (V, E)$ consisting of $|V|$ nodes and a set of $|E|$ edges. Each node contains a fixed value (here: sugar amount at agent's current location). Nodes exchange information about these values through some given protocol (e.g., multicast or newscast). (Defined inversely: the graph can be considered the connectivity graph of the used communication protocol.) For formalisation, let a random node i communicate a value x. Let ι be the number of nodes that has received value x. Note that is a function of time, i.e., over time more agents get informed about value x. Let $\iota(t)$ denote the number of informed agents at time t. This function defines the dissemination of information, but does not state *how fast* the information spreads.

Based on some properties of G, we can characterise $\iota(t)$ and define the rate at which information spreads. Candidates for these properties are the average path length, connection degree and "small-world parameter" p. Let the *shortest path* length between two nodes i and j, denoted by $sp(i, j)$, be the minimum number of edges needed to traverse to reach j from i. The average path length, denoted by $SP(V)$, is the average of the shortest path lengths between any two nodes. (A small average path length is important for dissemination of information.) We define the *connection degree* as the average number of edges leaving a node, i.e., the average out-degree of the graph nodes, defined by $O(V) = \Sigma_{v \in V} o(v)/n$, where $o(v)$ denotes the out-degree of node v. Finally, the "small-world parameter" p is defined in [10]: starting from a ring lattice with n nodes and k edges per vertex, each edge is rewired with probability p. This allows to tune graphs between regular ($p = 0$) and disorder ($p = 1$); about the intermediate region $0 < p < 1$ is little known. Many graph structures found in nature have some p value that is in this intermediate region.

5.2 Value of information

For the VUSCAPE world, it is difficult to precisely define the value of information. Consider the following example in which this is easier (from which we may be able to define the value of information in VUSCAPE).

Assume that we have a graph in which all nodes contain some given value. Assume as well that we have an communication protocol by which nodes can exchange information about their value. Every node can calculate the average of the values that it has received. After some time (depending on the information dissemination rate of the communication protocol), each node contains the true average. This assumes that the values do not change value. If we drop this assumption, there is some probability that a node value remains that same over time. Given such a probability, we can (analytically or empirically) calculate the average time at which node values remain the same; hence, this is our information value υ.

Currently, we have not yet defined information value loss in VUSCAPE, but the described example suffices to explain our approach to researching the information speed hypothesis that we describe next. From our empirical findings, we expect the loss of information value to be extremely high in VUSCAPE.

5.3 Information speed hypothesis

Consider Figure 3 illustrating our approach towards investigating the information speed hypothesis and its usefulness. This hypothesis says that there is a fundamental relation between the dissemination of information and loss of information value. Here, information dissemination is determined by the communication protocol used by the agents, whereas the loss of information value is defined in the environment.

In Figure 3, we have plotted two hypothetical curves for σ and υ. Although we need to conduct further research to investigate the actual curves, the diagram illustrates the usefulness of the information speed hypothesis. Note that the axes have different semantics for the two curves. For υ, the x-axis is the probability that information does not change during an iteration and on the y-axis the average number of iterations that information stays the same; for σ, the x-axis is some graph property indicating the information dissemination (for example, average out-degree or average path length) and the y-axis shows the number of iterations it takes for everyone to know about disseminated information.

Assuming that we have obtained the two curves for a particular domain (either by theoretical analysis or empirically), then we can make calculations on the informations dissemination vs value ratio.

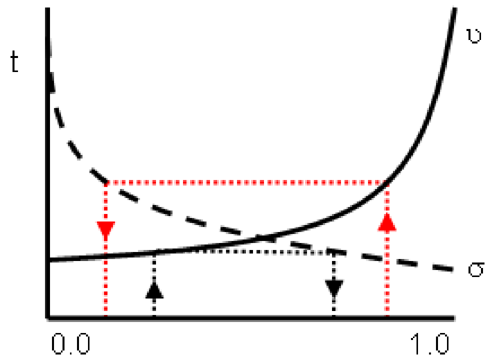


Figure 3: Illustrative example of analysis approach to test the information speed hypothesis.

For the grey (red) dotted line in Figure 3, we take a high probability that the information remains the same (easy world), follow the dotted line and see that we need a low information dissemination value (e.g., low average out-degree of the communication connectivity graph). For the converse, consider the black dotted line that shows for a tough world (information changes quickly), we need a high information dissemination value.

6. CONCLUSIONS

The investigation presented in this paper aimed at studying the effects of different communication methods in an artificial society. In particular, we compared population dynamics resulting from using multicast and newscast communication. In both systems the tendency of agents to communicate are genetic features that undergo variation and selection.

Our empirical results show that in the given setup populations using newscast communication typically die out, while populations using multicast communication do not. Closer inspection discloses that the newscast communication allows, unintentionally, the propagation of timed out messages. Simply stating: the information on good locations (with much sugar) becomes misleading "too" rapidly, causing inappropriate decisions and reducing the viability of the population. While at the first sight this might seem a negative result, these observations are valuable because of the insight they provide about the niche of newscast based communication protocols.

Our insight is based on identifying two essential processes (information being spread and information loosing its value) and considering the ratio of the speeds of these processes as a basic indicator. The first process is the spreading of information through the epidemic protocol of the newscast model. The second one is the decrease of the worth, or validity, of information that is being spread. In general, if the information looses its value significantly faster than it is spread, then many agents receive information that is of limited worth, useless, or even harmful (misleading). This perspective can explain the outcomes of our experiments. Namely, in the VUScape world as used here information looses its value immediately after being used. That is, the information becomes worthless after an agent acts upon it and goes to an indicated location to eat the sugar. In fact, this is the most extreme case of decreasing values: information here has a (Boolean) validity that can switch from 1 to 0 within one cycle. From these observations we can also conclude that it is not the centralized nature of the multicasting communication that makes it better than newscast in VUScape. Rather, it is the feature that consumed information is removed from the message board.

Based on these insights we are also able to circumscribe the niche of newscast based communication: It consists of such environments where the validity of information outlasts the period needed to spread the information. For instance, if the information concerns non-volatile properties of the world in question.

Future research efforts will be grouped along a number of threads. Firstly, we need to set up a quantitative model based on the above theory and perform experimental analysis of the corresponding processes under various circumstances. Secondly, we intend to research communication protocols in different environmental settings. As for the third thread we propose research on the advantage for agents of being in each other's list of friends, where the update mechanism of this list favours to keep those who have sent useful information in the past.

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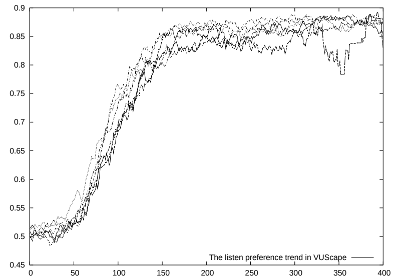
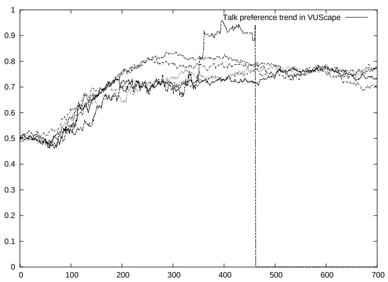
MULTICAST



LISTEN PREFERENCE



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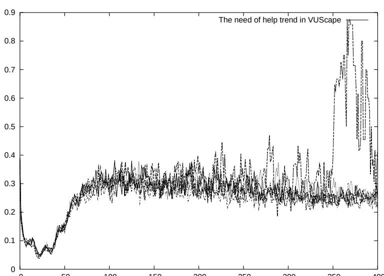

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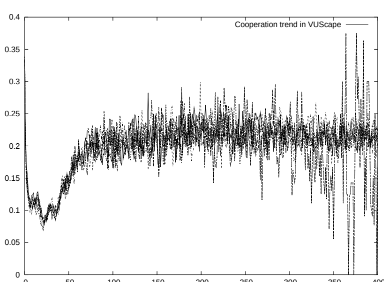
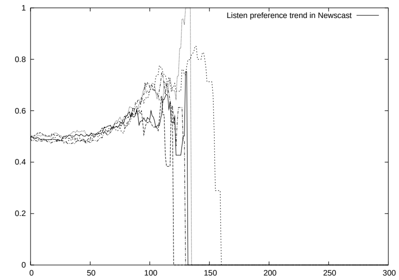


COOPERATION

NEWSCAST



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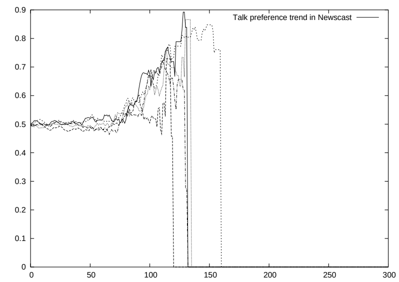

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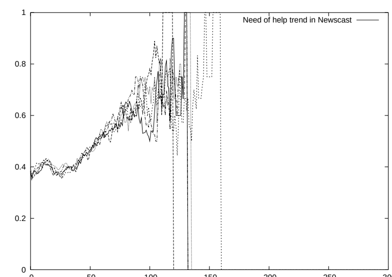

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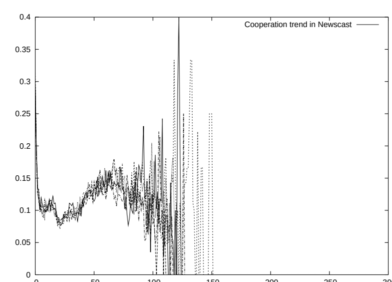

COOPERATION