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A Comparison Study for Two Fuzzy-based Systems: Improving Reliability and Security of JXTA-Overlay P2P Platform

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Received: date / Accepted: date

Abstract The reliability of peers is very important for safe communication in Peer-to-Peer (P2P) systems. The reliability of a peer can be evaluated based on the reputation and interactions with other peers to provide different services. However, for deciding the peer reliability there are needed many parameters, which make the problem NP-hard. In this paper, we present two fuzzy-based systems (called FBRS1 and FBRS2) to improve the reliability of JXTA-Overlay P2P platform. In FBRS1, we considered three input parameters: Number of Interactions (NI), Security (S), Packet Loss (PL) to decide the Peer Reliability (PR). In FBRS2, we considered four input parameters: NI, S, PL and Local Score (LS) to decide the PR. We compare the proposed systems by computer simulations. Comparing the complexity of FBRS1 and FBRS2, the FBRS2 is more complex than FBRS1. However, it also considers the local score, which makes it more reliable than FBRS1.

Keywords P2P · Fuzzy System · Reliability · Number of Interactions · Security · Local Score · JXTA-Overlay Platform

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1 Introduction

The Internet is growing every day and the performance of computers is increased exponentially. However, the Internet architecture is based on Client/Server (C/S) topology, therefore can not use efficiently the clients features. Also, with appearance of new technologies such as ad-hoc networks, sensor networks, body networks, wireless mesh networks, vehicular networks, new network devices and applications will appear Kulla et al. (2013); Barolli et al. (2003); Yang et al. (2012); Yousaf et al. (2014); Oda et al. (2014). Therefore, it is very important to monitor, control and optimize these network devices via communication channels. However, in large-scale networks such as Internet, it is very difficult to control the network devices, because of the security problems.

In order to make the networks secure many security devices are used. The firewalls are used for checking the information between private and public networks. The information is transmitted according to some decided rules and it is very difficult to change the network security policy. Also, there are many small networks and Intranets that do not allow the information coming from other networks. Therefore, recently many researchers are working on Peer-to-Peer (P2P) networks, which are able to overcome the firewalls, NATs and other security devices without changing the network policy. Thus, P2P architectures will be very important for future distributed systems and applications. In such systems, the computational burden of the system can be distributed to peer nodes of the system. Therefore, in decentralized systems users become themselves actors by sharing, contributing and controlling the resources of the system. This characteristic makes P2P systems very interesting for the development of decentralized applications Xhafa et al. (2007); Barolli et al. (2007).

In Xhafa et al. (2007), it is proposed a JXTA-based P2P system. JXTA-Overlay is a middleware built on top of the JXTA specification, which defines a set of protocols that standardize how different devices may communicate and collaborate among them. It abstracts a new layer on the top of JXTA through a set of primitive operations and services that are commonly used in JXTA-based applications and provides a set of primitives that can be used by other applications, which will be built on top of the overlay, with complete independence. JXTA-Overlay provides a set of basic functionalities, primitives, intended to be as complete as possible to satisfy the needs of most JXTA-based applications.

In P2P systems, each peer has to obtain information of other peers and propagate the information to other peers through neighboring peers. Thus, it is important for each peer to have some number of neighbor peers. Moreover, it is more significant to discuss if each peer has reliable neighbor peers. In reality, each peer might be faulty or might send obsolete, even incorrect information to the other peers. If a peer is faulty, other peers which receive incorrect information on the faulty peer might reach a wrong decision. Therefore, it is critical to discuss how a peer can trust each of its neighbor peers Aikebaier et al. (2010); Watanabe et al. (2007).

The reliability of peers is very important for safe communication in P2P system. The reliability of a peer can be evaluated based on the reputation and interactions with other peers to provide services. However, in order to decide the peer reliability are needed many parameters, which make the problem NP-hard.

Fuzzy Logic (FL) is the logic underlying modes of reasoning which are approximate rather than exact. The importance of FL derives from the fact that most modes of human reasoning and especially common sense reasoning are approximate in nature. FL uses linguistic variables to describe the control parameters. By using relatively simple linguistic expressions it is possible to describe and grasp very complex problems. A very important property of the linguistic variables is the capability of describing imprecise parameters.

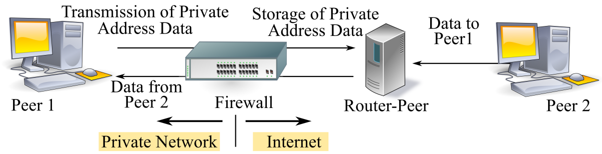

Fig. 1 P2P communication.

The concept of a fuzzy set deals with the representation of classes whose boundaries are not determined. It uses a characteristic function, taking values usually in the interval [0, 1]. The fuzzy sets are used for representing linguistic labels. This can be viewed as expressing an uncertainty about the clear-cut meaning of the label. But important point is that the valuation set is supposed to be common to the various linguistic labels that are involved in the given problem.

The fuzzy set theory uses the membership function to encode a preference among the possible interpretations of the corresponding label. A fuzzy set can be defined by examplification, ranking elements according to their typicality with respect to the concept underlying the fuzzy set Asai et al. (1992).

In this paper, we present two fuzzy-based systems (called FBRS1 and FBRS2) to improve the reliability of JXTA-Overlay P2P platform. In FBRS1, we considered three input parameters: Number of Interactions (NI), Security (S), Packet Loss (PL) to decide the Peer Reliability (PR). In FBRS2, we considered four input parameters: NI, S, PL and Local Score (LS) to decide the PR. We compare the proposed systems by computer simulations. Comparing the complexity of FBRS1 and FBRS2, the FBRS2 is more complex than FBRS1. However, it also considers the local score, which makes it more reliable than FBRS1.

The structure of this paper is as follows. In Section 2, we introduce the Project JXTA and JXTA-Overlay. In Section 3, we introduce FL used for control. In Section 4, we present the proposed fuzzy-based systems. In Section 5, we discuss the simulation results. Finally, conclusions and future work are given in Section 6.

2 JXTA Technology and JXTA-Overlay

2.1 JXTA Technology

JXTA technology is a generalized group of protocols that allow different devices to communicate and collaborate among them. JXTA offers a platform covering basic needs in developing P2P networks Brookshier et al. (2002).

By using the JXTA framework, it is possible that a peer in a private network can be connected to a peer in the Internet by overcoming existing firewalls as shown in Fig. 1. In this figure, the most important entity is the router peer. A router peer is any peer which supports the peer endpoint protocol and routing messages between peer in the JXTA networks. The procedure to overcome the firewall is as follows.

– In the Router Peer is stored the private address of Peer1 by using the HTTP protocol to pass the firewall from Peer1.
– The Router Peer receives the data from Peer2 and access the Private address of Peer1 to transmit the data.

JXTA is an interesting alternative for developing P2P systems and groupware tools to support online teams of students in virtual campuses. In particular, it is appropriate for file sharing given that the protocols allow to develop either pure or mixed P2P networks. This last property is certainly important since pure P2P systems need not the presence of a server for managing the network.

2.2 JXTA-Overlay

JXTA-Overlay project is an effort to use JXTA technology for building an overlay on top of JXTA offering a set of basic primitives (functionalities) that are most commonly needed in JXTA-based applications Spaho et al. (2014); Matsuo et al. (2009); Ogata et al. (2010); Spaho et al. (2010). The proposed overlay comprises the following primitives:

– peer discovery,
– peer's resources discovery,
– resource allocation,
– task submission and execution,
– file/data sharing, discovery and transmission,
– instant communication,
– peer group functionalities (groups, rooms etc.),
– monitoring of peers, groups and tasks.

This set of basic functionalities is intended to be as complete as possible to satisfy the needs of JXTA-based applications Xhafa et al. (2009, 2010). The overlay is built on top of JXTA layer and provides a set of primitives that can be used by other applications, which on their hand, will be built on top of the overlay, with complete independence. The JXTA-Overlay project has been developed using the ver-2.3 JXTA libraries. In fact, the project offers several improvements

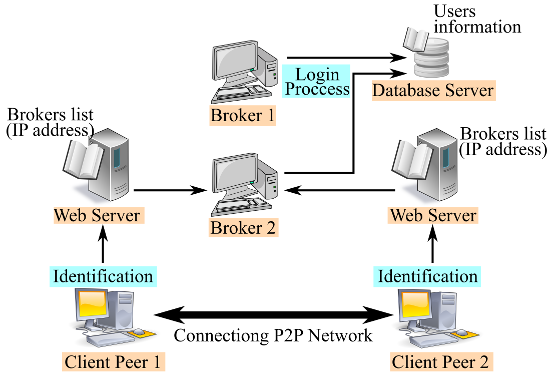

Fig. 2 Structure of JXTA-Overlay system.

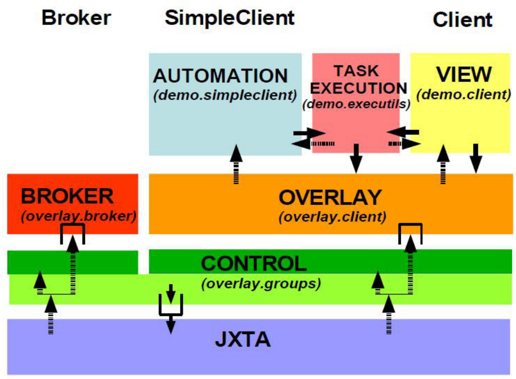

Fig. 3 Internal Architecture of JXTA-Overlay.

of the original JXTA protocols/services in order to increase the reliability of JXTA-based distributed applications and to support group management and file sharing.

The architecture of the P2P distributed platform we have developed using JXTA technology has two main peers: Broker and Client. Altogether these two peers form a new overlay on top of JXTA. The structure of JXTA-Overlay system is shown in Fig. 2.

2.3 Internal Architecture of JXTA-Overlay

Except Broker and Client peers, the JXTA-Overlay has also SimpleClient peers as shown in Fig. 3. The control layer interacts with the JXTA layer, and is divided into two parts: a lower part with functionality common to any kind of peer, and a higher part with functionality specific to Brokers and Clients.

– The common part provides functionality for doing JXTA messaging, discovery and advertisement.
– The Broker specific part provides functionality for managing groups of Brokers and keeping broker statistics.

– The Client specific part provides functionality for managing groups of Clients, keeping client statistics, managing its shareable files, managing the user configuration and creating the connection with a Broker.

The lower part enqueues the JXTA messages to be sent. Whenever a message arrives, the JXTA layer fires an event to the lower layer, which in turn fires a notifications to the upper layers.

3 Application of Fuzzy Logic for Control

The ability of fuzzy sets and possibility theory to model gradual properties or soft constraints whose satisfaction is matter of degree, as well as information pervaded with imprecision and uncertainty, makes them useful in a great variety of applications.

The most popular area of application is Fuzzy Control (FC), since the appearance, especially in Japan, of industrial applications in domestic appliances, process control, and automotive systems, among many other fields.

3.1 FC

In the FC systems, expert knowledge is encoded in the form of fuzzy rules, which describe recommended actions for different classes of situations represented by fuzzy sets.

In fact, any kind of control law can be modeled by the FC methodology, provided that this law is expressible in terms of "if ... then ..." rules, just like in the case of expert systems. However, FL diverges from the standard expert system approach by providing an interpolation mechanism from several rules. In the contents of complex processes, it may turn out to be more practical to get knowledge from an expert operator than to calculate an optimal control, due to modeling costs or because a model is out of reach.

3.2 Linguistic Variables

A concept that plays a central role in the application of FL is that of a linguistic variable. The linguistic variables may be viewed as a form of data compression. One linguistic variable may represent many numerical variables. It is suggestive to refer to this form of data compression as granulation Kandel (1991).

The same effect can be achieved by conventional quantization, but in the case of quantization, the values are intervals, whereas in the case of granulation the values are overlapping fuzzy sets. The advantages of granulation over quantization are as follows:

– it is more general;
– it mimics the way in which humans interpret linguistic values;
– the transition from one linguistic value to a contiguous linguistic value is gradual rather than abrupt, resulting in continuity and robustness.

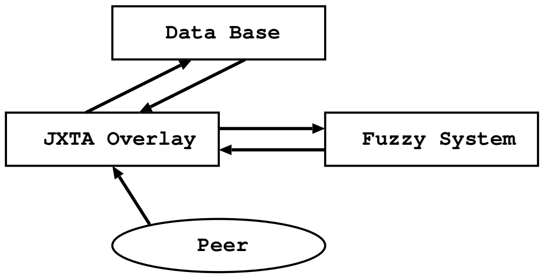

Fig. 4 Proposed peer reliability system.

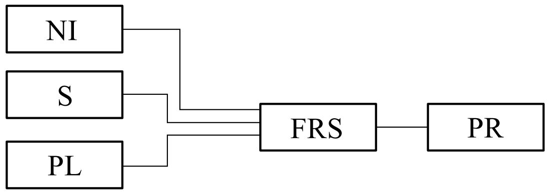

Fig. 5 Structure of FBRS1.

3.3 FC Rules

FC describes the algorithm for process control as a fuzzy relation between information about the conditions of the process to be controlled, x and y, and the output for the process z. The control algorithm is given in "if ... then ..." expression, such as:

If x is small and y is big, then z is medium;
If x is big and y is medium, then z is big.

These rules are called *FC rules*. The "if" clause of the rules is called the antecedent and the "then" clause is called consequent. In general, variables x and y are called the input and z the output. The "small" and "big" are fuzzy values for x and y, and they are expressed by fuzzy sets.

Fuzzy controllers are constructed of groups of these FC rules, and when an actual input is given, the output is calculated by means of fuzzy inference.

3.4 Control Knowledge Base

There are two main tasks in designing the control knowledge base. First, a set of linguistic variables must be selected which describe the values of the main control parameters of the process. Both the input and output parameters must be linguistically defined in this stage using proper term sets. The selection of the level of granularity of a term set for an input variable or an output variable plays an important role in the smoothness of control. Second, a control knowledge base must be developed which uses the above linguistic description of the input and output parameters. Four methods Zimmermann (2001); McNeill and Thro (2014); Zadeh and Kacprzyk (1992); Procyk and Mamdani (1979) have been suggested for doing this:

- expert's experience and knowledge;
- modeling the operator's control action;
- modeling a process;
- self organization.

Among the above methods, the first one is the most widely used. In the modeling of the human expert operator's knowledge, fuzzy rules of the form "If Error is small and Change-in-error is small then the Force is small" have been used in several studies Klir and Folger (1988); Munakata and Jani (1994). This method is effective when expert human operators can express the heuristics or the knowledge that they use in controlling a process in terms of rules of the above form.

3.5 Defuzzification Methods

The defuzzification operation produces a non-FC action that best represent the membership function of an inferred FC action. Several defuzzification methods have been suggested in literature. Among them, four methods which have been applied most often are:

- Tsukamoto's Defuzzification Method Konig and Litz (1994); If monotonic membership functions are used, then a crisp control action can be calculated by:

$$Z^* = \frac{\sum_{i=1}^{n} \omega_i x_i}{\sum_{i=1}^{n} \omega_i} \tag{1}$$

  where n is the number of rules with firing strength (ω_i) greater then 0 and x_i is the amount of control action recommended by rule i.
- The Center of Area (COA) Method; Assuming that a control action with a pointwise membership function μ_C has been produced. The COA method calculates the center of gravity of the distribution for the control action. Assuming a discrete universe of discourse, we have:

$$Z^* = \frac{\sum_{j=1}^{q} z_j \mu_C(z_j)}{\sum_{j=1}^{q} \mu_C(z_j)} \tag{2}$$

Table 1 FRB of FBRS1.

Rule No.	NI	S	PL	PR
1	F	Lo	Sm	MG
2	F	Lo	Me	BD
3	F	Lo	Ma	EB
4	F	Mi	Sm	PG
5	F	Mi	Me	MG
6	F	Mi	Ma	BD
7	F	Hi	Sm	G
8	F	Hi	Me	PG
9	F	Hi	Ma	MG
10	A	Lo	Sm	PG
11	A	Lo	Me	MG
12	A	Lo	Ma	BD
13	A	Mi	Sm	G
14	A	Mi	Me	PG
15	A	Mi	Ma	MG
16	A	Hi	Sm	VG
17	A	Hi	Me	G
18	A	HI	Ma	PG
19	B	Lo	Sm	G
20	B	Lo	Me	PG
21	B	Lo	Ma	MG
22	B	Mi	Sm	VG
23	B	Mi	Me	G
24	B	Mi	Ma	PG
25	B	Hi	Sm	VVG
26	B	Hi	Me	VG
27	B	HI	Ma	G

  where q is the number of quantization levels of the output, z_j is the amount of control output at the quantization level j and $\mu_C(z_j)$ represents its membership function value in C.
- The Mean of Maximum (MOM) Method; The MOM method generates a crisp control action by averaging the support values which their membership values reach the maximum. For a discrete universe of discourse, this is calculated by:

$$Z^* = \sum_{j=1}^{l} \frac{z_j}{l} \tag{3}$$

  where l is the number of quantized z values which reach their maximum memberships.
- Defuzzification when Output of Rules are Function of Their Inputs. FC rules may be written as a function of their inputs. For example,

  Rule i : If X is A_i and Y is B_i then Z is $f_i(X, Y)$;

  assuming that α_i is the firing strength of the rule i, then:

$$Z^* = \frac{\sum_{i=1}^{n} \alpha_i f_i(x_i, y_i)}{\sum_{j=1}^{n} \alpha_i}. \tag{4}$$

Table 2 FRB of FBRS2.

Rule No.	NI	S	PL	LS	PR	Rule No.	NI	S	PL	LS	PR
1	F	Lo	Sm	S	MG	41	A	Mi	Me	M	PG
2	F	Lo	Sm	M	EB	42	A	Mi	Me	H	BD
3	F	Lo	Sm	H	EB	43	A	Mi	Ma	S	VVG
4	F	Lo	Me	S	PG	44	A	Mi	Ma	M	G
5	F	Lo	Me	M	BD	45	A	Mi	Ma	H	MG
6	F	Lo	Me	H	EB	46	A	Hi	Sm	S	VG
7	F	Lo	Ma	S	G	47	A	Hi	Sm	M	PG
8	F	Lo	Ma	M	MG	48	A	Hi	Sm	H	BD
9	F	Lo	Ma	H	EB	49	A	Hi	Me	S	VVG
10	F	Mi	Sm	S	PG	50	A	Hi	Me	M	G
11	F	Mi	Sm	M	BD	51	A	Hi	Me	H	MG
12	F	Mi	Sm	H	EB	52	A	Hi	Ma	S	VVG
13	F	Mi	Me	S	G	53	A	Hi	Ma	M	VG
14	F	Mi	Me	M	MG	54	A	Hi	Ma	H	PG
15	F	Mi	Me	H	EB	55	B	Lo	Sm	S	VG
16	F	Mi	Ma	S	VG	56	B	Lo	Sm	M	PG
17	F	Mi	Ma	M	PG	57	B	Lo	Sm	H	BD
18	F	Mi	Ma	H	BD	58	B	Lo	Me	S	VVG
19	F	Hi	Sm	S	G	59	B	Lo	Me	M	G
20	F	Hi	Sm	M	MG	60	B	Lo	Me	H	MG
21	F	Hi	Sm	H	EB	61	B	Lo	Ma	S	VVG
22	F	Hi	Me	S	VG	62	B	Lo	Ma	M	VG
23	F	Hi	Me	M	PG	63	B	Lo	Ma	H	PG
24	F	Hi	Me	H	BD	64	B	Mi	Sm	S	VVG
25	F	Hi	Ma	S	VVG	65	B	Mi	Sm	M	G
26	F	Hi	Ma	M	G	66	B	Mi	Sm	H	MG
27	F	Hi	Ma	H	MG	67	B	Mi	Me	S	VVG
28	A	Lo	Sm	S	PG	68	B	Mi	Me	M	VG
29	A	Lo	Sm	M	BD	69	B	Mi	Me	H	PG
30	A	Lo	Sm	H	EB	70	B	Mi	Ma	S	VVG
31	A	Lo	Me	S	G	71	B	Mi	Ma	M	VVG
32	A	Lo	Me	M	MG	72	B	Mi	Ma	H	G
33	A	Lo	Me	H	EB	73	B	Hi	Sm	S	VVG
34	A	Lo	Ma	S	VG	74	B	Hi	Sm	M	VG
35	A	Lo	Ma	M	PG	75	B	Hi	Sm	H	PG
36	A	Lo	Ma	H	BD	76	B	Hi	Me	S	VVG
37	A	Mi	Sm	S	G	77	B	Hi	Me	M	VVG
38	A	Mi	Sm	M	MG	78	B	Hi	Me	H	G
39	A	Mi	Sm	H	EB	79	B	Hi	Ma	S	VVG
40	A	Mi	Me	S	VG	80	B	Hi	Ma	M	VVG
						81	B	Hi	Ma	H	VG

4 Proposed Fuzzy-Based Peer Reliability Systems

To complete a certain task in JXTA-Overlay network, peers have to interact with unknown peers. Thus, it is important that peers must select reliable peers to interact. The NI, S, PL and LS that a peer has with other peers in JXTA-Overlay P2P network are very important factors that affect the peer reliability. In every transaction, peers receive a file and evaluate reliability based on these parameters. Selfish peers that benefits from the system without contributing any resources to the network have a low reliability. Every time a peer joins JXTA-Overlay, parameters are fuzzified using fuzzy system, and based on the decision of the fuzzy system a reliable peer is selected. After peer selection, the data for this peer are saved in the database as shown in Fig. 4.

In Liu et al. (2014), we already proposed a peer reliability system with three parameters: NI, S and PL to decide the PR. The structure of this system called Fuzzy Reliability System (FBRS1) is shown in Fig. 5 and the membership functions for FBRS1 are shown in Fig. 6. The Fuzzy Rule Base (FRB) of FBRS1 is shown in Table 1 and consists of 27 rules.

In this work, we consider the Local Score (LS) as a new parameter together with three parameters to decide the PR. We call this system FBRS2. Every time a peer joins JXTA-Overlay, four parameters are fuzzified using fuzzy system, and based on the decision of fuzzy system a reliable peer is selected. After peer selection, the data for this peer are saved in the database.

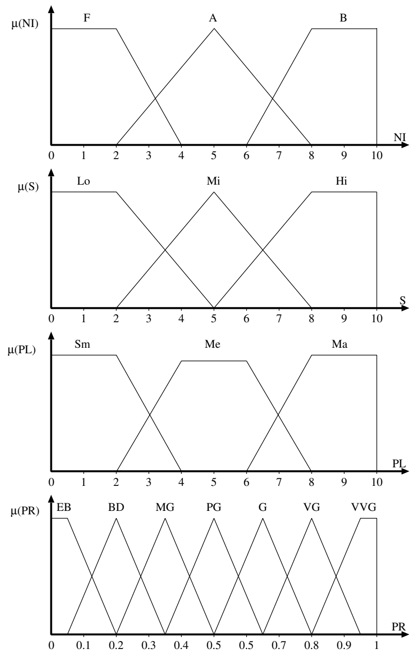

Fig. 6 Membership functions of FBRS1.

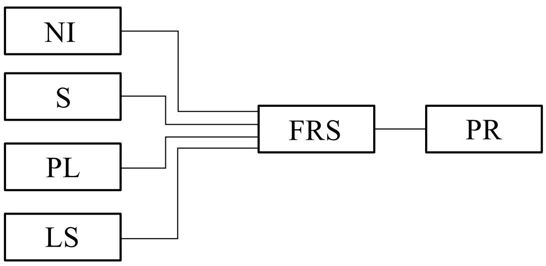

Fig. 7 Structure of FBRS2.

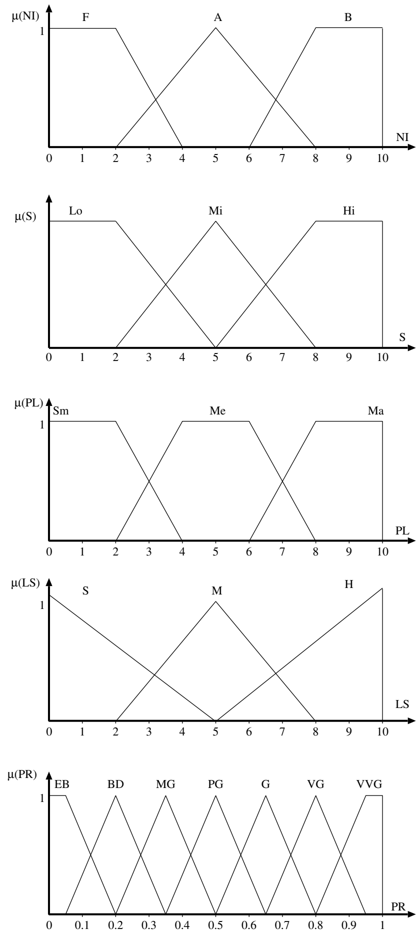

Fig. 8 Membership functions of FBRS2.

The structure of FBRS2 and membership functions are shown in Fig. 7 and Fig. 8, respectively. In Table 2, we show the FRB of FBRS2, which consists of 81 rules.

The input parameters for peer-reliability assessment are: NI, S, PR and LS while the output linguistic parameter is PR. The term sets of *NI*, *S*, *PL* and *LS* are defined respectively as:

$$\begin{aligned}
NI &= \{Few,\ Average,\ Big\} = \{F,\ A,\ B\};\\
S &= \{Low,\ Middle,\ High\} = \{Lo,\ Mi,\ Hi\};\\
PL &= \{Small,\ Medium,\ Many\} = \{Sm,\ Me,\ Ma\};\\
LS &= \{Small,\ Medium,\ High\} = \{S,\ M,\ H\}.
\end{aligned}$$

and the term set for the output *PR* is defined as:

$$PR = \begin{pmatrix} Extremely\ Bad \\ Bad \\ Minimally\ Good \\ Partially\ Good \\ Good \\ Very\ Good \\ Very\ Very\ Good \end{pmatrix} = \begin{pmatrix} EB \\ BD \\ MG \\ PG \\ G \\ VG \\ VVG \end{pmatrix}$$

5 Simulation Results

In this section, we present the simulation results for our proposed systems. We decided the number of term sets by carrying out many simulations. These simulation results were carried out in MATLAB.

For FBRS1, we show the relation between NI, S, PL and PR in Figs. 9 to 11. In these simulations, we consider the PL as a constant parameter. From the simulation results we can clearly distinguish 3 zones. When LS is less than 2.5 units the PR is very small. A middle zone (more than 2.5 units but less than 7.5 units),

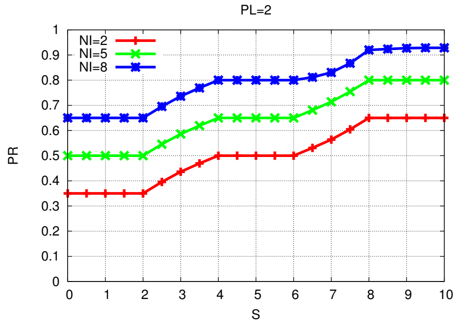

Fig. 9 Peer reliability for PL=2 (FBRS1).

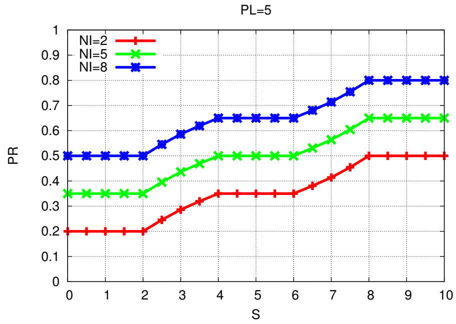

Fig. 10 Peer reliability for PL=5 (FBRS1).

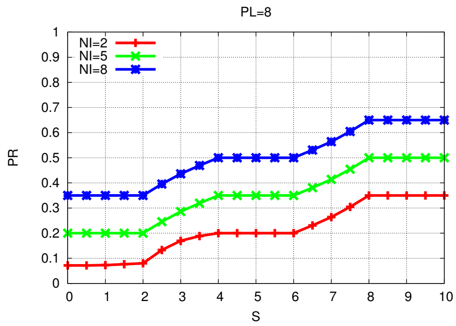

Fig. 11 Peer reliability for PL=8 (FBRS1).

where the PR increases proportionally with the increase of LS. For more than 8 units there is a third zone where the PR is high. In Fig. 9, we consider the PL value 2 units. When the S increases, the PR is increased. Also, when the NI increases, the PR is increased. In Figs. 10 and 11, we increase the PL values to 5 and 8 units, respectively. We see that, when the PL increases, the PR is decreased.

In Fig. 12(a), we show the relation between NI, S, PL, LS and PR when PL and LS are considered as constant parameters. With the increase of NI and S, the PR increases, the same as the FBRS1.

In Fig. 12(b) and Fig. 12(c), we increase the LS value to 5 and 8 units, respectively. When the peer provides a high local score with high probability, the reliability is increased. However because the packet loss is small, the PR values are higher.

In Fig. 13 and Fig. 14, we increase the PL value to 5 and 8 units, respectively. When the peer provides many packet loss, the reliability is decreased much more.

Comparing the complexity of FBRS1 and FBRS2, the FBRS2 is more complex than FBRS1. However, it also considers the local score, which makes it more reliable than FBRS1.

6 Conclusions and Future Work

In order to select a reliable peer to connect with other peers in JXTA-Overlay platform, we presented two fuzzy-based systems to decide the PR. We took into consideration three input parameters: NI, S and PL for FBRS1 and four input parameters: NI, S, PL and LS for FBRS2. We compared proposed systems (FBRS1 and FBRS2) by computer simulations.

From the simulations results, we conclude as follows.

- PR is high when it interacts with other peers to exchange their resources.
- With the increasing of the packet loss, the PR is decreased.
- When security is high, the reliability is high.
- When the LS is increased, PR is increased.
- Comparing the complexity of FBRS1 and FBRS2, the FBRS2 is more complex than FBRS1. However, it also considers the local score, which makes it more reliable than FBRS1.
- The proposed system can choose reliable peers to connect in JXTA-Overlay platform.

In the future, we would like to make extensive simulations and carry out experiments with JXTA-Overlay platform.

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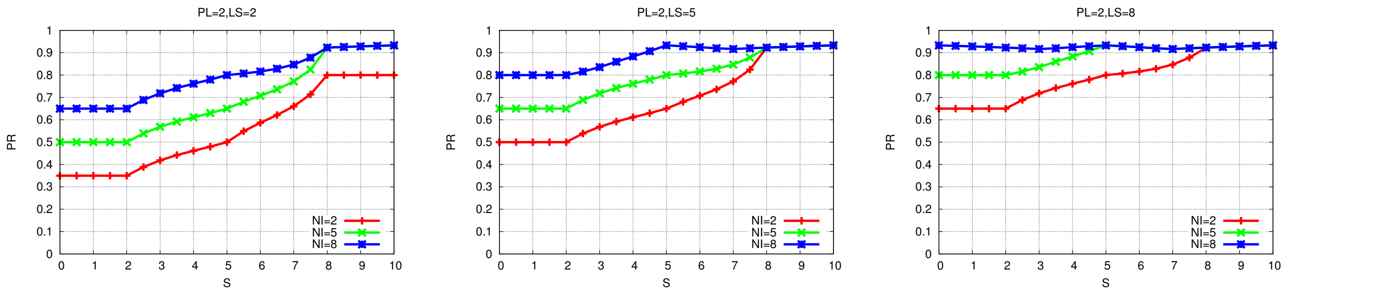
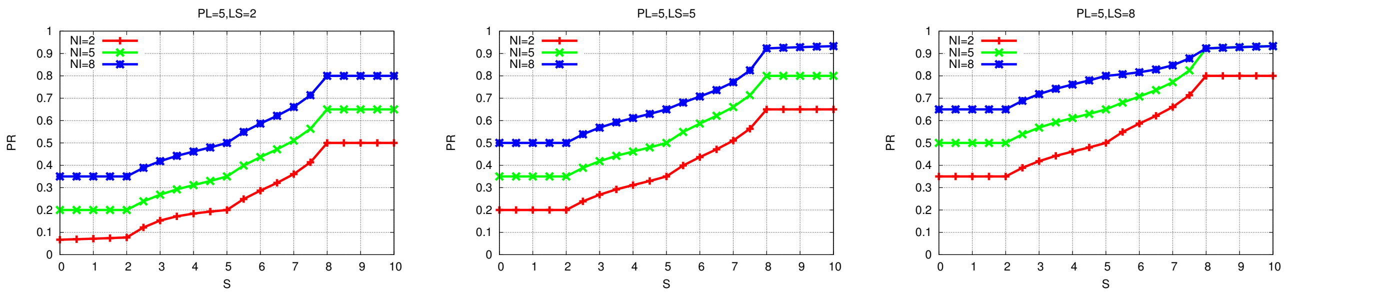


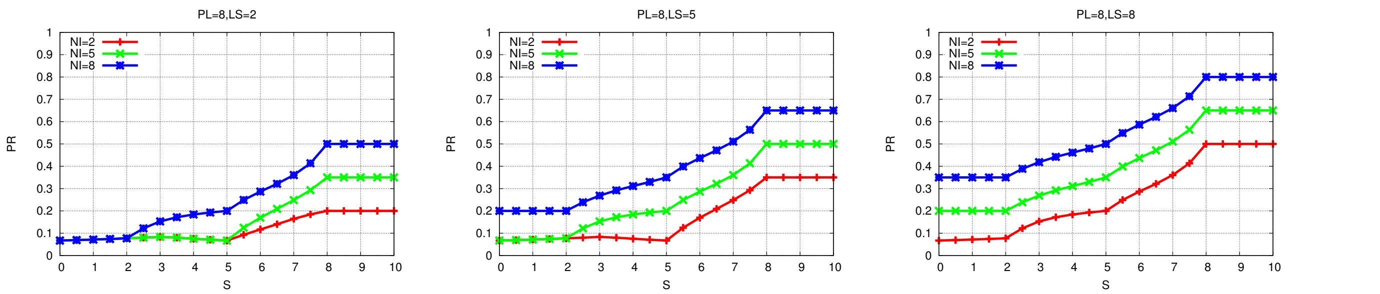
(a) LS=2 (b) LS=5 (c) LS=8

Fig. 12 Peer reliability for different LS value when the PL=2 (FBRS2).



(a) LS=2 (b) LS=5 (c) LS=8

Fig. 13 Peer reliability for different LS value when the PL=5 (FBRS2).



(a) LS=2 (b) LS=5 (c) LS=8

Fig. 14 Peer reliability for different LS value when the PL=8 (FBRS2).

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