Design and implementation of testbed using IoT and P2P technologies: improving reliability by a fuzzy-based approach

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Abstract: The term IoT has recently become popular to emphasise the vision of a global infrastructure of networked physical objects. IoT is a new type of internet application which enables the things/objects in our environment to be active participants with other members of the network, by sharing their information on a global scale using the same internet protocol (IP) that connects to the internet. In P2P systems, each peer has to obtain information of other peers and propagate the information to other peers through neighbouring peers. Thus, it is important for each peer to have some number of neighbour peers. Moreover, it is more significant to discuss if each peer has reliable neighbour peers. In reality, each peer might be faulty or might send obsolete, even incorrect information to the other peers. We have implemented a P2P platform called JXTA-overlay, which defines a set of protocols that standardise how different devices may communicate and collaborate among them. 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 this paper, we present the design and implementation of a testbed using IoT and P2P technologies. We also present two fuzzy-based systems (FPRS1 and FPRS2) to improve the reliability of the proposed approach. We make a comparison study between the fuzzy-based systems. Comparing the complexity of FPRS1 and FPRS2, the FPRS2 is more complex than FPRS1. However, it considers also the sustained communication time which makes the platform more reliable.

Keywords: internet of things; P2P systems; JXTA-overlay; fuzzy logic; network reliability; intelligent algorithm.

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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, home networking, new network devices and applications will appear. Therefore, it is very important to monitor, control and optimise 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 decentralised 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 decentralised applications (Xhafa et al., 2007; Barolli et al., 2007).

In Xhafa et al. (2007) and Spaho et al. (2014), 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 standardise 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 neighbouring peers. Thus, it is important for each peer to have some number of neighbour peers. Moreover, it is more significant to discuss if each peer has reliable neighbour 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 that 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 neighbour 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 then 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.

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 a fuzzy-based peer reliability system (FPRS1) for JXTA-overlay P2P platform considering three parameters: data download speed (DDS), local score (LS) and number of interactions (NI) to decide the peer reliability (PR). We also implement another FPRS (FPRS2) considering four parameters: DDS, LS, NI and sustained communication time (SCT) to decide the PR.

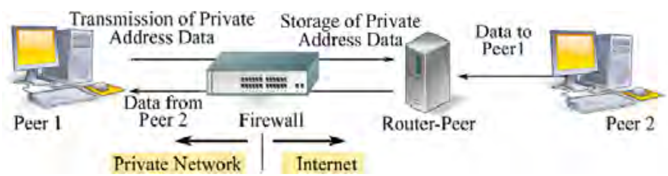
The structure of this paper is as follows. In Section 2, we introduce the Project JXTA and JXTA-overlay. In Section 3, we explain an overview of internet of thing (IoT). In Section 4, we introduce FL used for control. In Section 5, we show the description and implementation of IoT testbed. In Section 6, we present the proposed fuzzy-based peer trustworthiness system. In Section 7, we discuss the experimental and simulation results. Finally, conclusions and future work are given in Section 8.

2 JXTA technology and JXTA-overlay

2.1 JXTA technology

JXTA technology is a generalised 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., 2007).

Figure 1 P2P communication (see online version for colours)



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 Figure 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 peer 1 by using the HTTP protocol to pass the firewall from peer 1
- the router peer receives the data from peer 2 and access the private address of peer 1 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 (Ogata et al., 2010; Spaho et al., 2010; Liu et al., 2015a, 2015b, 2015c; Matsuo et al., 2009; Umezaki et al., 2012). The proposed overlay comprises the following primitives:

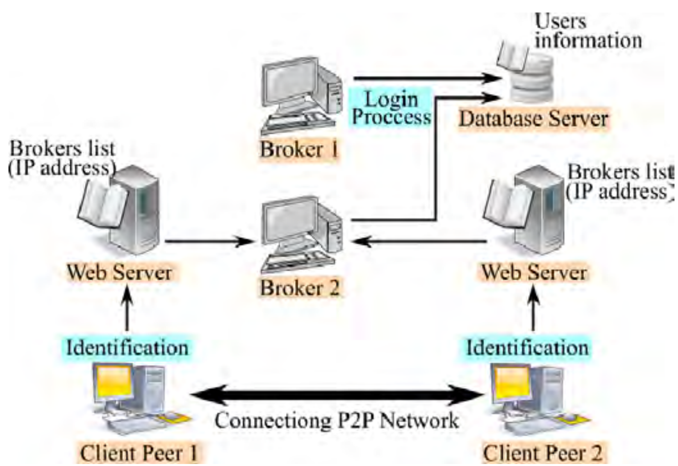
- peer discovery
- peer’s resources discovery
- resource allocation
- task submission and execution
- file/data sharing, discovery and transmission

- 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. 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 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 Figure 2.

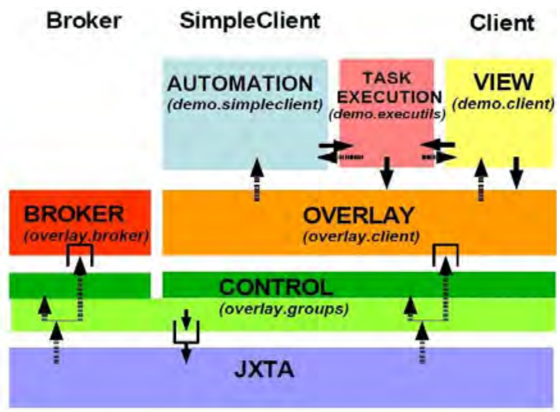
Figure 2 Structure of JXTA-overlay system (see online version for colours)



2.3 Internal architecture of JXTA-overlay

Except broker and client peers, the JXTA-overlay has also simple client peers as shown in Figure 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.

Figure 3 Internal architecture of JXTA-overlay (see online version for colours)



- 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.

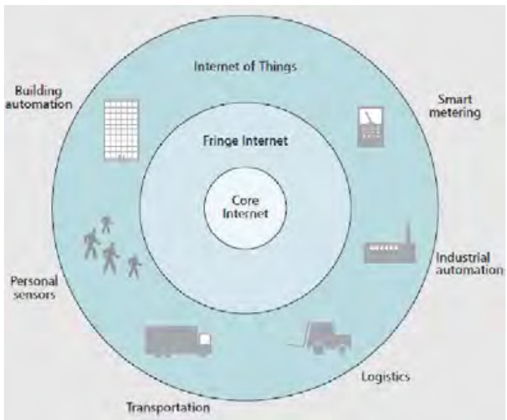
The lower part enqueues the JXTA messages to be sent. Whenever a message arrives, the JXTA layer fires an event to the lower layer, which in turn fires a notifications to the upper layers.

3 Internet of things

The descriptive models for IoT are introduced based on two attributes ('being an internet', 'relating to thing's information') and four different features (only for thing's information, coded by UID or EPC, stored in RFID electronic tag, uploaded by non-contact reading with RFID reader) (Huang and Li, 2010).

The IoT creates human-machine or machine-to-machine communications. In this way the things/objects are capable of recognising events and changes in their surroundings and are acting and reacting autonomously largely without human intervention in an appropriate way. The major objectives for IoT applications and services are the creation of smart environments/spaces and self-aware things for smart transport, products, cities, buildings, energy, health, social interaction and living applications in Figure 4.

Figure 4 IoT model (see online version for colours)



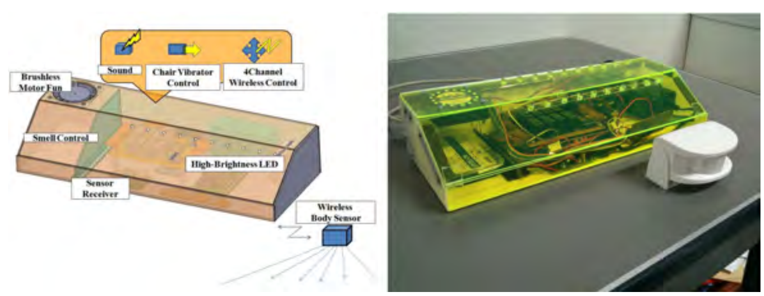
3.1 SmartBox

The SmartBox device is integrated with our system as a useful tool for monitoring and controlling children activities. The size of the SmartBox is 35 × 7 × 12 cm (see Figure 5). The SmartBox has the following sensors and functions:

- body sensor for detecting body and hand movement
- chair or bed vibrator control for vibrating the chair or bed
- light control for adjusting the room light
- smell control for controlling the room smell
- sound control to emit relaxing sounds.
- remote control socket for controlling AC 100 V socket (on-off control).

These functions can calm and relax students and increase concentration on tasks.

Figure 5 SmartBox functions (see online version for colours)



In order to keep the learner motivated in learning activities we are going to use the features of SmartBox device: the chair vibrator control, light control, smell control, sound control.

- *chair or bed vibrator control for vibrating the chair:* through sensory integration, physicalvibrations of chair will relax and calm the child
- *light control for adjusting the room light:* if the child is a visual learner, in order to capture child's attention we can use the computers screen to show coloured images and use the light control for changing the room light
- *Smell control for controlling the room smell:* if the child likes certain smells/perfumes we can put the perfume of that smell to get the attention
- *sound control to emit relaxing sounds:* if the child accepts auditory stimuli we can use this to ge this attention and maintain focus in learning.

3.2 RFID-based system

The GUI of RFID-based system is shown in Figure 6. Tagging physical objects to find and analyse data about the object is one way the IoT can be used in education. Using our proposed and implemented system, a child or leaner can learn new words through touching the physical objects that are in their vocabulary list. Each physical object would have a RFID tag placed on the item (see Figure 7). When this tag is read by a RFID reader or scanned by an application running on a computer or mobile device it would prompt the device to open up a page of information or send a command for an action to happen (see Figure 8). RFID tags can be created and attached by the parents for each of the physical items in the vocabulary list. When the child places the RFID card on the RFID reader, it will say the word for the item in their native language. Touching the item will give to the child another sense to be engaged and may help them learn new words faster.

Figure 6 GUI of our system (see online version for colours)

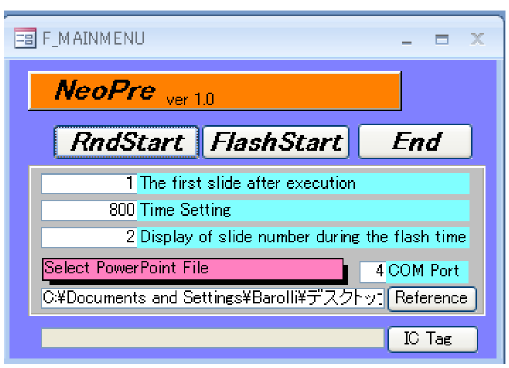
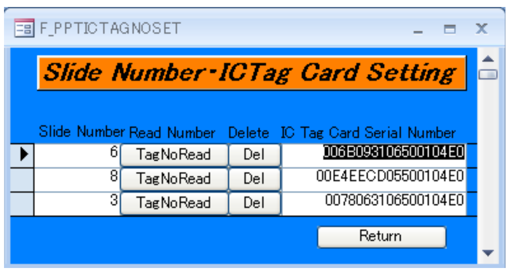


Figure 7 IC tag card and IC tag reader (see online version for colours)

Figure 8 Saving information in IC tag cards (see online version for colours)



4 Application of FL 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.

4.1 Fuzzy control

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 modelled 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 modelling costs or because a model is out of reach.

4.2 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 quantisation, but in the case of quantisation, the values are intervals, whereas in the case of granulation the values are overlapping fuzzy sets. The advantages of granulation over quantisation 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.

4.3 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.

4.4 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, 1991; McNeill and Thro, 1994; Zadeh and Kacprzyk, 1992; Procyk and Mamdani, 1979) have been suggested for doing this:

- expert's experience and knowledge
- modelling the operator's control action
- modelling a process
- self-organisation.

Among the above methods, the first one is the most widely used. In the modelling 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; Umezaki et al., 2011; 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.

4.5 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
- the centre of area (COA) method
- the mean of maximum (MOM) method
- defuzzification when output of rules are function of their inputs.

5 Implementation of IoT testbed

The structure of IoT-based e-learning testbed is shown in Figures 9 and 10 (Yamada et al., 2015). Our testbed is composed of five Raspberry Pi B+ (Raspberry Pi Foundation, 2007; Oda et al., 2015a, 2015b).

The experimental scenario of our IoT testbed is shown in Figure 11. Figure 12 shows the snapshots of nodes in the testbed. The experimental parameters for the LoS scenario are shown in Tables 1 and 2.

We collected data for 3 metrics: throughput, delay and jitter. These data are collected by using the Iperf, which is a network testing tool (Iperf, 2007). The Iperf was originally developed by NLANR/DAST as a modern alternative for measuring TCP and UDP bandwidth performance. The Iperf allows the tuning of various parameters and UDP characteristics.

Figure 9 Image of IoT system (see online version for colours)

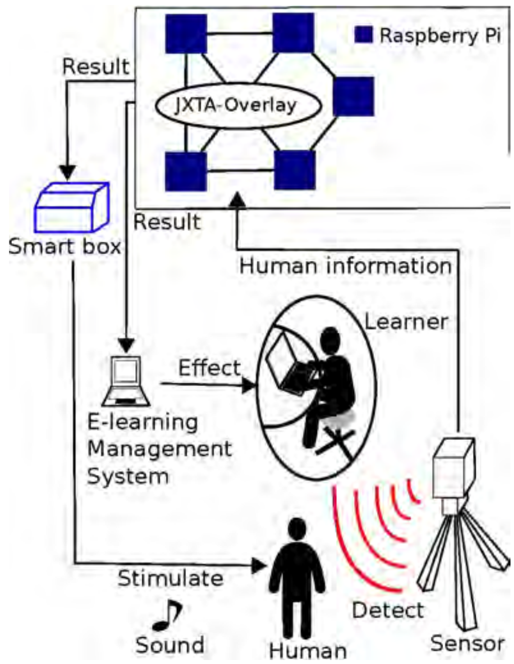


Figure 10 Wireless P2P over ad hoc network

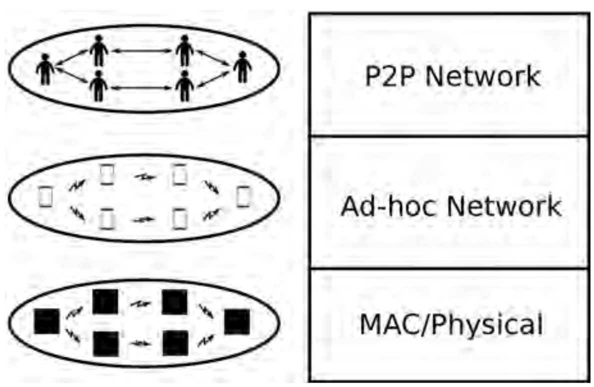


Figure 11 Experimental scenario

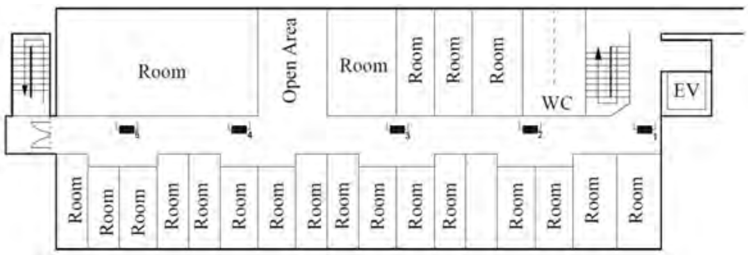


Figure 12 Snapshot of nodes in the testbed, (a) node 1 (b) node 2 (c) node 3 (d) node 4 (e) node 5 (see online version for colours)

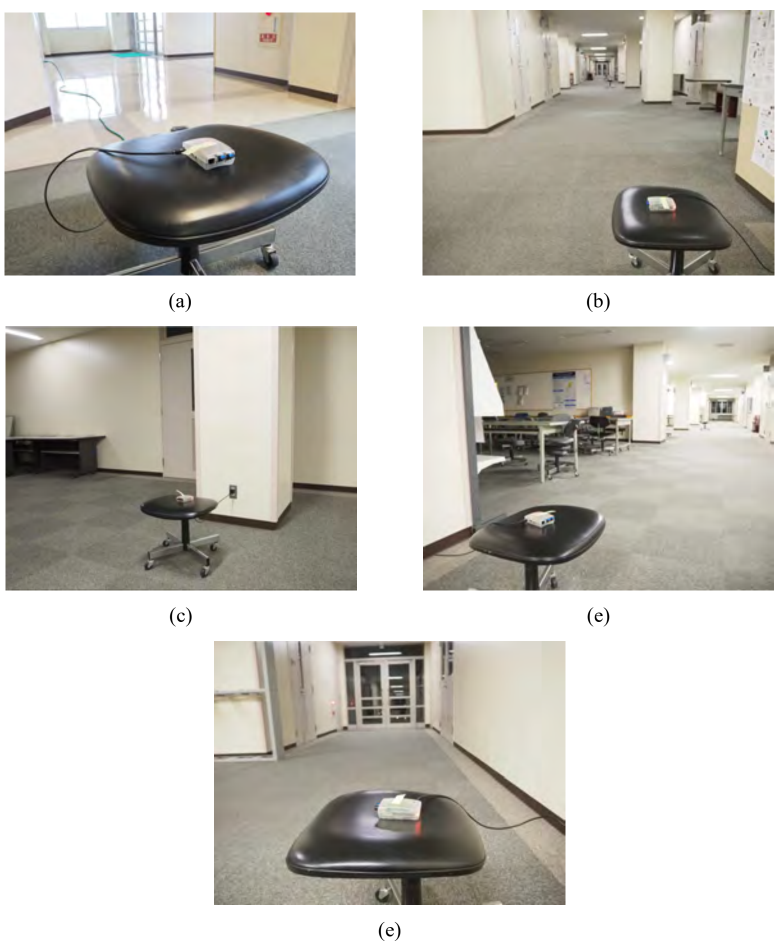


Table 1 Experimental parameters

Functions	*Values*
OS	Raspbian
Number of trials	100
Duration	80 [sec]
Number of mesh nodes	5
MAC	IEEE 802.11n
Routing protocol	OLSR
OLSRd	OLSRd 0.6.7.1
Transport protocol	UDP
Flow type	CBR
Encryption protocol	WEP
Bit rate	512 [Kbps]

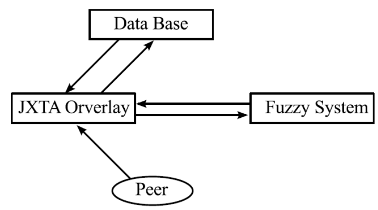
Table 2 OLSRd parameters

Functions	*Values*
Hello interval time	5.0 [sec]
Hello validity	40.0 [sec]
TC interval time	2.0 [sec]
TC validity	256.0 [sec]
MID interval time	18.0 [sec]
MID validity	324.0 [sec]
HNA interval time	18.0 [sec]
HNA validity	108.0 [sec]

6 Proposed fuzzy-based peer reliability systems

To complete a certain task in JXTA-overlay network, peers often have to interact with unknown peers. The data download speed that a peer has with other peers in JXTA-overlay P2P network is a very important factor that affects the peer reliability. In every transaction, peers receive a file and evaluate reliability of the senders with local score from the file. Another important parameter that is connected with peer reliability is the sustained communication time. 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 fuzzy system a reliable peer is selected. After peer selection, the data for this peer are saved in the database as shown in Figure 13.

Figure 13 Proposed peer reliability system



The structure FPRS1 is shown in Figure 14 and the membership functions for FPRS1 are shown in Figure 15. The fuzzy rule base (FRB) of FPRS1 is shown in Table 3 and consists of 27 rules.

In this work, we consider the sustained communication time as a new parameter together with three parameters to decide the PR. We call this system FPRS2. The structure of FPRS2 and membership functions are shown in Figures 16 and 17, respectively. In Table 4, we show the FRB of FPRS2, which consists of 81 rules.

The term sets of *DDS*, *LS* and *NI* and *SCT* are defined respectively as:

$$DDS = \{Slow, Middle, Far\} = \{Sl, Mi, Fa\};$$

$$LS = \{Small, Medium, Many\} = \{Sm, Me, Ma\};$$

$$NI = \{Few, Average, Big\} = \{F, A, B\};$$

$$SCT = \{Short, Medium, Long\} = \{Sh, Me, Long\}.$$

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

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

Figure 14 Structure of FPRS1

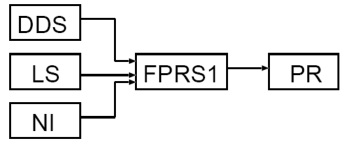


Figure 15 Membership functions of FPRS1

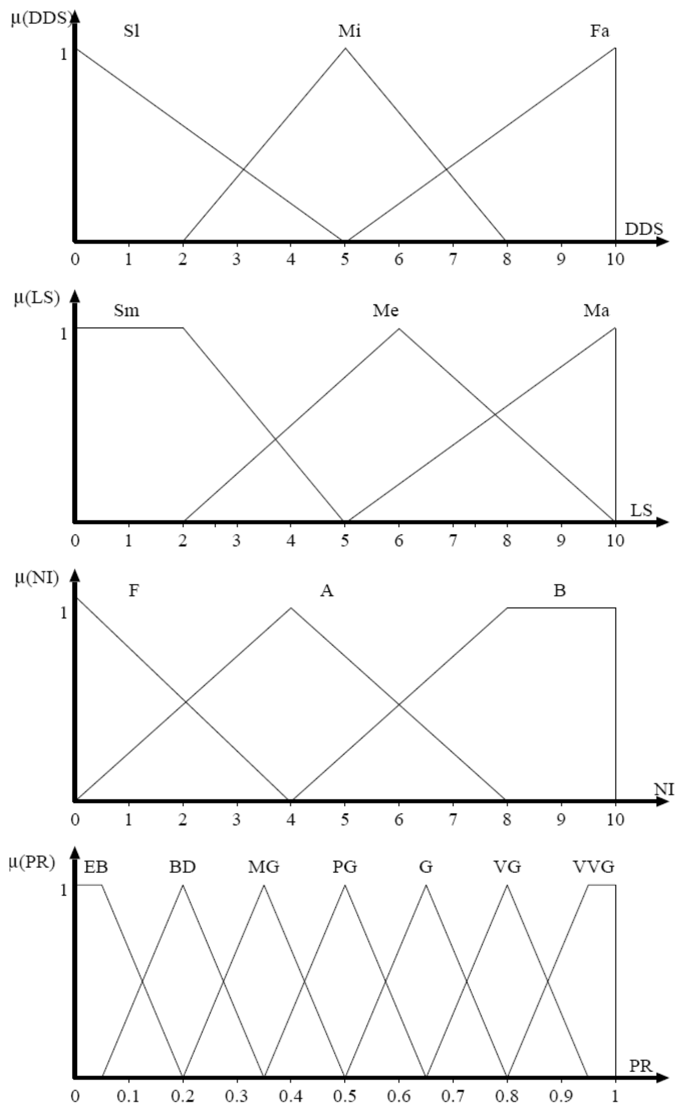


Table 3 FRB of FPRS1

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

Figure 16 Structure of FPRS2

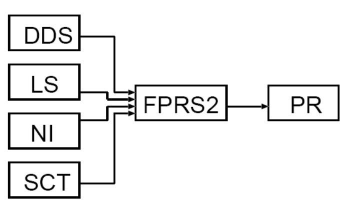


Figure 17 Membership functions of FPRS2

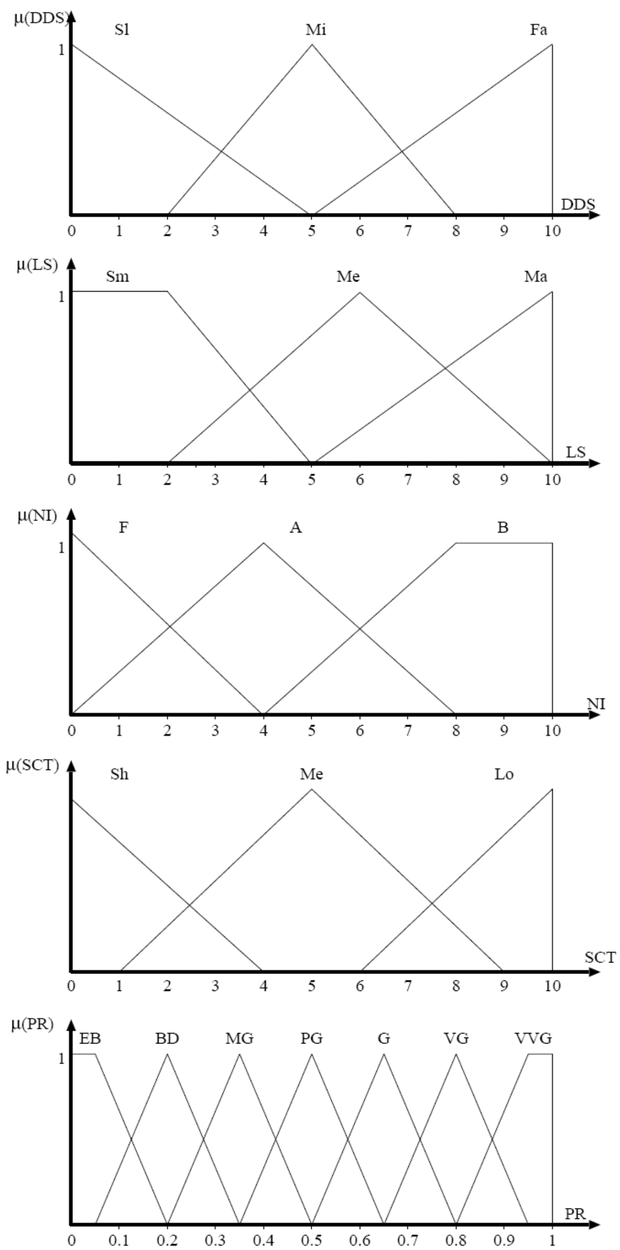


Table 4 FRB of FPRS2

Rule no.	*DDS*	*LS*	*NI*	*SCT*	*PR*	*Rule no.*	*DDS*	*LS*	*NI*	*SCT*	*PR*
1	Sl	Sm	F	Sh	EB	36	Mi	Sm	B	Lo	VG
2	Sl	Sm	F	Me	EB	37	Mi	Me	F	Sh	EB
3	Sl	Sm	F	Lo	EB	38	Mi	Me	F	Me	BD
4	Sl	Sm	A	Sh	EB	39	Mi	Me	F	Lo	MG
5	Sl	Sm	A	Me	EB	40	Mi	Me	A	Sh	MG
6	Sl	Sm	A	Lo	BD	41	Mi	Me	A	Me	PG
7	Sl	Sm	B	Sh	BD	42	Mi	Me	A	Lo	G
8	Sl	Sm	B	Me	MG	43	Mi	Me	B	Sh	PG
9	Sl	Sm	B	Lo	PG	44	Mi	Me	B	Me	G
10	Sl	Me	F	Sh	EB	45	Mi	Me	B	Lo	VG
11	Sl	Me	F	Me	EB	46	Mi	Ma	F	Sh	VVG
12	Sl	Me	F	Lo	BD	47	Mi	Ma	F	Me	BD
13	Sl	Me	A	Sh	EB	48	Mi	Ma	F	Lo	MG
14	Sl	Me	A	Me	BD	49	Mi	Ma	A	Sh	G
15	Sl	Me	A	Lo	MG	50	Mi	Ma	A	Me	PG
16	Sl	Me	B	Sh	MG	51	Mi	Ma	A	Lo	G
17	Sl	Me	B	Me	PG	52	Mi	Ma	B	Sh	VG
18	Sl	Me	B	Lo	G	53	Mi	Ma	B	Me	VG
19	Sl	Ma	F	Sh	EB	54	Mi	Ma	B	Lo	VVG
20	Sl	Ma	F	Me	BD	55	Fa	Sm	F	Sh	VVG
21	Sl	Ma	F	Lo	MG	56	Fa	Sm	F	Me	BD
22	Sl	Ma	A	Sh	BD	57	Fa	Sm	F	Lo	MG
23	Sl	Ma	A	Me	MG	58	Fa	Sm	A	Sh	PG
24	Sl	Ma	A	Lo	G	59	Fa	Sm	A	Me	MG
25	Sl	Ma	B	Sh	PG	60	Fa	Sm	A	Lo	PG
26	Sl	Ma	B	Me	G	61	Fa	Sm	B	Sh	VG
27	Sl	Ma	B	Lo	VG	62	Fa	Sm	B	Me	G
28	Mi	Sm	F	Sh	EB	63	Fa	Sm	B	Lo	VG
29	Mi	Sm	F	Me	EB	64	Fa	Me	F	Sh	VVG
30	Mi	Sm	F	Lo	BD	65	Fa	Me	F	Me	PG
31	Mi	Sm	A	Sh	BD	66	Fa	Me	F	Lo	G
32	Mi	Sm	A	Me	MG	67	Fa	Me	A	Sh	PG
33	Mi	Sm	A	Lo	PG	68	Fa	Me	A	Me	VG
34	Mi	Sm	B	Sh	MG	69	Fa	Me	A	Lo	VVG
35	Mi	Sm	B	Me	PG	70	Fa	Me	B	Sh	VG

Table 4 FRB of FPRS2 (continued)

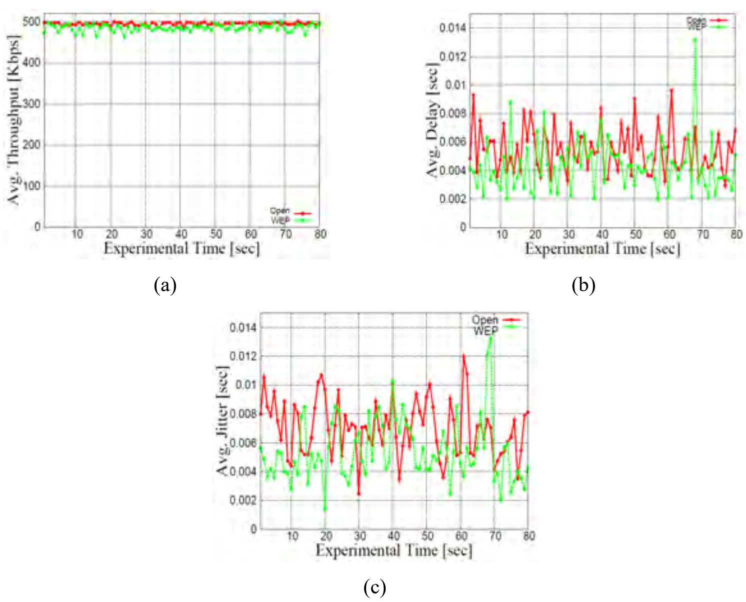
Rule no.	*DDS*	*LS*	*NI*	*SCT*	*PR*	*Rule no.*	*DDS*	*LS*	*NI*	*SCT*	*PR*
71	Fa	Me	B	Me	VVG	76	Fa	Ma	A	Sh	VG
72	Fa	Me	B	Lo	VVG	77	Fa	Ma	A	Me	VVG
73	Fa	Ma	F	Sh	PG	78	Fa	Ma	A	Lo	VVG
74	Fa	Ma	F	Me	G	79	Fa	Ma	B	Sh	VVG
75	Fa	Ma	F	Lo	VG	80	Fa	Ma	B	Me	VVG
						81	Fa	Ma	B	Lo	VVG

7 Experimental and simulation results

7.1 Experimental results

For evaluation, we used a single flow from node 1 to node 5. In Figure 18, we show the experimental results for LoS scenario. Source and destination nodes are always 1 and 5, respectively. In Figure 18(a), we show the average throughput from node 1 to node 5. The average throughput value of none encryption and WEP is 494 and 485 [Kbps], respectively. In Figure 18(b), we can see that the delay of none encryption and WEP is lower than 0.009 and 0.01318 [sec], respectively. In Figure 18(c), we can see that the jitter of none encryption and WEP is lower than 0.011 and 0.01319 [sec], respectively.

Figure 18 Experimental results for node 1 → 5, (a) avg. throughput (b) avg. delay (c) avg. jitter (see online version for colours)



7.2 Simulation results

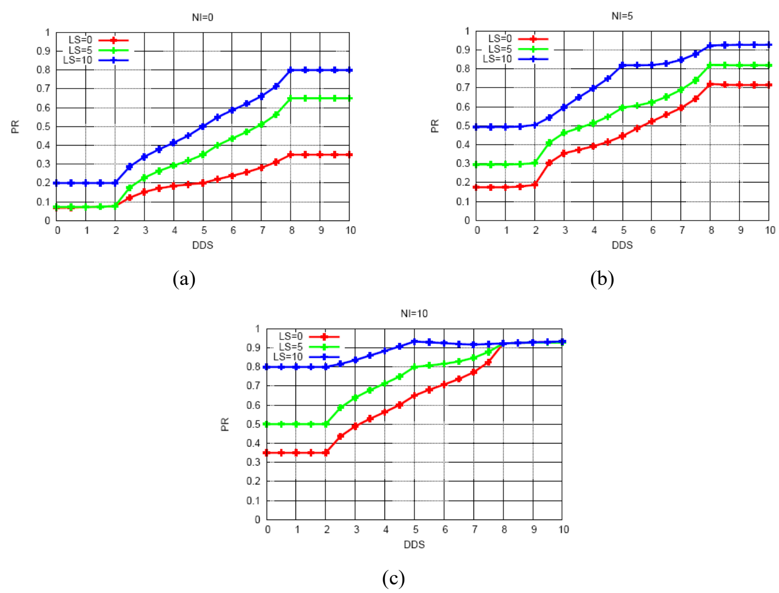
In this section, we present the simulation results for our proposed systems. In our systems, we decided the number of term sets by carrying out many simulations.

For FPRS1, we show the relation of DDS, LS, NI and PR in Figure 19. In this simulation, we consider the NI as a constant parameter. From the simulation results we can clearly distinguish three zones. When DDS is less than 2 units the PR is very small. For 2 to 8 units there is a second zone where the PR increases proportionally with the increase of DDS. For more than 8 units, the PR is high. As shown by these figures, with the increasing of NI, DDS and LS, the PR increases.

For FPRS2, in Figure 20, we show the relation of DDS, LS, NI, SCT and PR, when NI and SCT are considered as constant parameters. In this simulation SCT is 0, so the performance is almost the same with Figure 9.

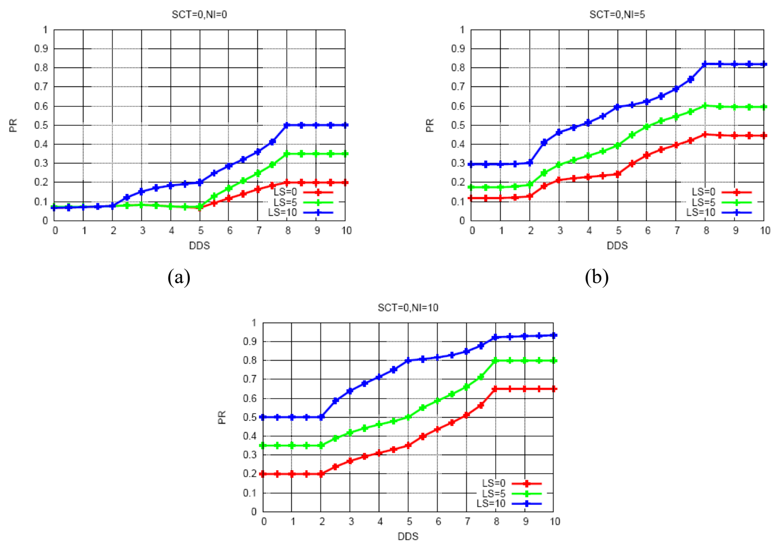
In Figures 21 and 22, we increase the SCT value to 5 and 10 units, respectively. With the increase of the SCT, the PR increases. When the SCT is high, the PR values of FPRS2 are higher than FPRS1. This shows that the SCT has a great effect on the reliability of proposed system.

Figure 19 Peer reliability for different NI (FPRS1), (a) NI = 0 (b) NI = 5 (c) NI = 10 (see online version for colours)



(a) (b) (c)

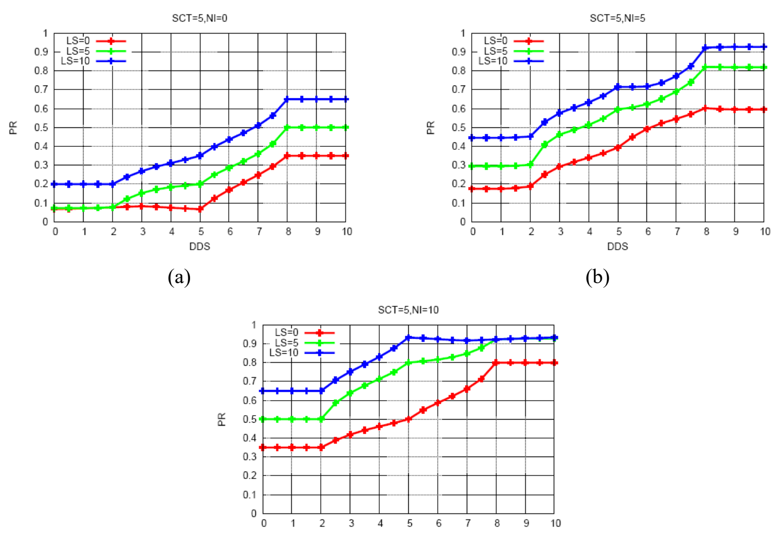
Figure 20 Peer reliability for different NI when the SCT = 0 (FPRS2), (a) NI = 0 (b) NI = 5 (c) NI = 10 (see online version for colours)



(a) (b)

(c)

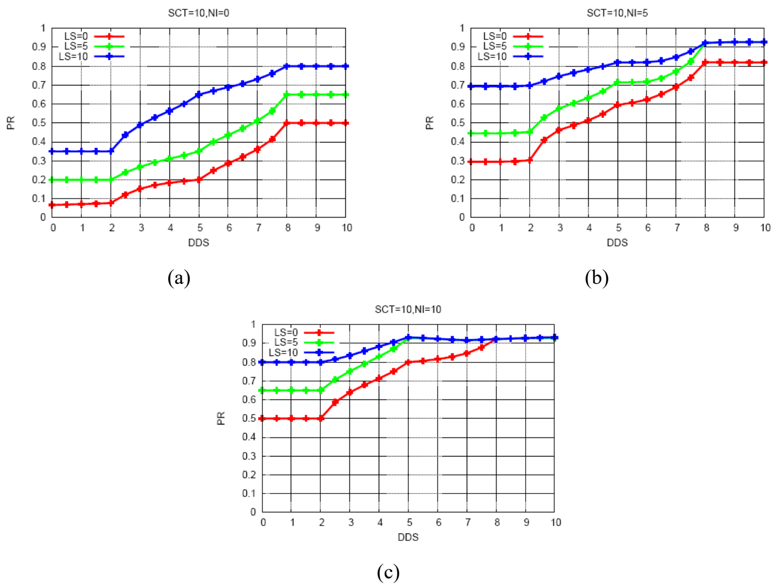
Figure 21 Peer reliability for different NI when the SCT = 5 (FPRS2), (a) NI = 0 (b) NI = 5 (c) NI = 10 (see online version for colours)



(a) (b)

(c)

Figure 22 Peer reliability for different NI when the SCT = 10 (FPRS2), (a) NI = 0 (b) NI = 5 (c) NI = 10 (see online version for colours)



8 Conclusions and future work

In this paper, we present the design and implementation of a testbed using IoT and P2P technologies. We took into consideration four parameters: DDS, LS, NI and SCT. We evaluated the performance of proposed system by computer simulations.

From experimental results, we found the following results:

- the average throughput value of none encryption and WEP was 494 and 485 [Kbps], respectively
- the average delay of none encryption and WEP is lower than 0.009 and 0.01318 [sec], respectively
- the average jitter of none encryption and WEP is lower than 0.011 and 0.01319 [sec], respectively
- the nodes in the testbed were communicating smoothly.

From the simulations results, we conclude as follows:

- When DDS, LS and NI are high, the reliability is high.
- With the increasing of the SCT, the PR is increased.
- The proposed system can choose reliable peers to connect in JXTA-overlay platform.

- Comparing the complexity, the FPRS2 is more complex than FPRS1. However, FPRS2 considers also the SCT, which makes the platform more reliable.

In the future, we would like to make extensive simulations to evaluate the proposed system and compare the performance of our proposed system with other systems.

References

Aikebaier, A., Enokido, T. and Takizawa, T. (2010) 'Reliable message broadcast schemes in distributed agreement protocols', *International Conference on Broadband, Wireless Computing, Communication and Applications (BWCCA-2010)*, pp.242–249.

Asai, K., Sugeno, M., Terano, T. and Aschmann, C.G. (1992) *Fuzzy Systems Theory and Its Applications*, Academic Press.

Barolli, L., Xhafa, F., Durresi, A. and de Marco, G. (2007) 'M3PS: a JXTA-based multi-platform P2P system and its web application tools', *International Journal of Web Information Systems*, Vol. 2, Nos. 3–4, pp.187–196.

Brookshier, D., Govoni, D., Krishnan, N. and Soto, J.C. (2002) *JXTA: Java P2P Programming*, Sams.

Huang, Y. and Li, G. (2010) 'Descriptive models for internet of things', *Proc. of Intelligent Control and Information Processing International Conference (ICICIP-2010)*, pp.483–486.

Iperf (2007) *The TCP/UDP Bandwidth Measurement Tool* [online] https://iperf.fr/.

Kandel, A. (1991) *Fuzzy Expert Systems*, CRC Press.

Klir, G.J. and Folger, T.A. (1988) *Fuzzy Sets, Uncertainty, and Information*.

Liu, Y., Sakamoto, S., Matsuo, K., Ikeda, M. and Barolli, L. (2015a) 'Improving reliability of JXTA-overlay platform: evaluation for e-learning and trustworthiness', *Journal of Mobile Multimedia*, Vol. 11, No. 2, pp.34–50.

Liu, Y., Sakamoto, S., Matsuo, K., Ikeda, M., Barolli, L. and Xhafa, F. (2015b) 'Improving reliability of JXTA-overlay P2P platform: a comparison study for two fuzzy-based systems', *Journal of High Speed Networks*, Vol. 21, No. 1, pp.27–45.

Liu, Y., Sakamoto, S., Matsuo, K., Ikeda, M., Barolli, L. and Xhafa, F. (2015c) 'Improvement of JXTA-overlay P2P platform: evaluation for medical application and reliability', *International Journal of Distributed Systems and Technologies (IJDST)*, Vol. 6, No. 2, pp.45–62.

Matsuo, K., Barolli, L., Kolici, V., Xhafa, F., Koyama, A. and Durresi, A. (2009) 'Stimulation effects of SmartBox for e-learning using JXTA-overlay P2P system', *International Conference on Complex, Intelligent and Software Intensive Systems (CISIS-2009)*, pp.231–238.

McNeill, F.M. and Thro, E. (1994) *Fuzzy Logic: A Practical Approach*, Academic Press.

Munakata, T. and Jani, Y. (1994) 'Fuzzy systems: an overview', *Communications of the ACM*, Vol. 37, No. 3, pp.68–76.

Oda, T., Barolli, A., Sakamoto, S., Barolli, L., Ikeda, M. and Uchida, K. (2015a) 'Implementation and experimental results of a WMN testbed in indoor environment considering LoS scenario', *The 29th IEEE International Conference on Advanced Information Networking and Applications (AINA-2015)*, pp.37–42.

Oda, T., Elmazi, D., Ishitaki, T., Barolli, A., Matsuo, K. and Barolli, L. (2015b) 'Experimental results of a Raspberry Pi based WMN testbed for multiple flows and distributed concurrent processing', The *10th International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA-2015)*, pp.201–206.

Ogata, Y., Matsuo, K., Spaho, E., Barolli, L. and Xhafa, F. (2010) 'Implementation of SmartBox end-device for a P2P system and its evaluation for e-learning and medical applications', *International Conference on Broadband, Wireless Computing, Communication and Applications (BWCCA-2010)*, pp.794–799.

Procyk, T.J. and Mamdani, E.H. (1979) 'A linguistic self-organizing process controller', *Automatica*, Vol. 15, No. 1, pp.15–30.

Raspberry Pi Foundation (2007) [online] http://www.raspberrypi.org/.

Spaho, E., Matsuo, K., Barolli, L., Xhafa, F., Arnedo-Moreno, J. and Kolici, V. (2010) 'Application of JXTA-overlay platform for secure robot control', *Journal of Mobile Multimedia*, Vol. 6, No. 3, pp.227–242.

Spaho, E., Sakamoto, S., Barolli, L., Xhafa, F. and Ikeda, M. (2014) 'Trustworthiness in P2P: performance behaviour of two fuzzy-based systems for JXTA-overlay platform', *Soft Computing*, Vol. 18, No. 9, pp.1783–1793.

Umezaki, K., Spaho, E., Ogata, Y., Barolli, L., Xhafa, F. and Iwashige, J. (2011) 'A fuzzy-based trustworthiness system for JXTA-overlay P2P platform', *Third International Conference on Intelligent Networking and Collaborative Systems (INCoS-2011)*, pp.484–489.

Umezaki, K., Spaho, E., Ogata, Y., Barolli, L., Xhafa, F. and Iwashige, J. (2012) 'A fuzzy-based trustworthiness system for JXTA-overlay P2P platform and its performance evaluation considering three parameters', *26th International Conference on Advanced Information Networking and Applications Workshops (WAINA-2012)*, pp.944–949.

Watanabe, K., Nakajima, Y., Enokido, T. and Takizawa, M. (2007) 'Ranking factors in peer-to-peer overlay networks', *ACM Transactions on Autonomous and Adaptive Systems (TAAS-2007)*, Vol. 2, No. 3, p.11.

Xhafa, F., Fernandez, R., Daradoumis, T., Barolli, L. and Caballé, S. (2007) 'Improvement of JXTA protocols for supporting reliable distributed applications in P2P systems', *International Conference on Network-Based Information Systems (NBiS-2007)*, pp.345–354.

Yamada, M., Oda, T., Matsuo, K. and Barolli, L. (2015) 'Design of an IoT-based e-learning testbed', *The 30th IEEE International Conference on Advanced Information Networking and Applications (IEEE AINA-2016)*, pp.720–724.

Zadeh, L.A. and Kacprzyk, J. (1992) *Fuzzy Logic for the Management of Uncertainty*, John Wiley & Sons, Inc.

Zimmermann, H-J. (1991) *Fuzzy Set Theory and Its Applications*, Springer Science & Business Media.