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Valuation of online social networks - An economic model and its application using the case of Xing.com

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P2P ARCHITECTURE FOR UBIQUITOUS SUPPLY CHAIN SYSTEMS

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Abstract

Ubiquitous information technologies like RFID allow for immediate, extensive and fine-grained capture of real world information. Scalable and efficient networks for exchange of this vast amount of information amongst companies are crucial for the economic exploitation of benefits of ubiquitous information technologies. Existing networks bear several limitations like risks of single-point-of-failures or bottlenecks, unequally distributed power and burdens as well as inflexibility through stringent structures and formats. In particular there is a need for improving the scalability of solutions and ensuring autonomy of network participants. In this paper we introduce a Peer-to-Peer-based architecture for exchanging distributed information, which are shared among participants of a supply chain facilitated with ubiquitous information technologies. This architecture builds on the well-established EPCglobal standards, but can be implemented as an autonomous network. Unlike other architectures it does not need central coordination mechanisms, because it is based on self-organizing Peer-to-Peer protocols. We argue that our architecture supports business processes especially of small and medium-sized enterprises better than other architectures. We provide a discussion about requirements for solutions and a simulation-based analysis of the proposed architecture.

Keywords: RFID, Peer-to-peer networks, Supply chain management, Ubiquitous systems

1 INTRODUCTION

Ubiquitous information technologies merge the virtual world with the real world in a seamless way, making embedded information and computing capabilities available anytime and anywhere (Weiser 1991). Gathering real world information with ubiquitous IT enables precise monitoring and controlling of physical objects, their current state, whereabouts, movements and their environmental conditions. Radio Frequency Identification (RFID) is a basic and mature ubiquitous IT, which is applied to automatically identify individual objects and to link related individual information. It has already been thoroughly tested and is in actual use in several companies. Case studies (Fosso Wamba et al. 2008, Loebbecke 2007) as well as analytical studies (Bendavid et al. 2008, Lee & Özer 2007) document its potential both to improve efficiency of business processes, their management and controlling, and to facilitate new services and concepts within the scope of an integrated Supply Chain Management (SCM) (McFarlane & Sheffi 2003, Angeles 2005). Examples are track and tracing of products, automatic inventory and item-level product lifecycle management. Still, RFID systems for SCM, which reach beyond a single organization's boundaries, are not yet widespread (Gaukler & Seifert & Hausman 2007).

While the decrease of production costs for RFID tags and readers is mainly dependent on technological advancements, the cost-benefit-ratio of the whole system is influenced by design and configuration of the system architecture (Asif & Mandviwalla 2005). A prominent solution is provided by EPCglobal (EPCglobal 2007), a comprehensive framework for standardized, integrated deployment of RFID in supply chains. EPCglobal and other existing solutions for interorganizational RFID systems still bear limitations. Among the main limitations are inefficient, centralized system structures and unbalanced powers between participants (users) and solution providers. Upcoming streams of information may not be manageable by these solutions or become very costly. Central coordination entities could turn out to be bottlenecks or even be attacked by offenders. Furthermore, those entities may also misuse their power. Joint adoption of RFID across the supply chain is still considered unfavorable by many companies. These conditions call for pursuing research in the field of interorganizational ubiquitous IT systems (Ngai et al. 2008, Curtin & Kauffman & Riggins 2007). Therefore we discuss network system architectures and propose a new architecture aiming at overcoming existing limitations. Our architecture enables companies to efficiently exchange locally stored information, captured by RFID systems, over an interorganizational, decentralized network. Our research focuses in particular on adoption of ubiquitous IT by small and medium-sized enterprises (SME).

The remainder of this article is structured as follows: In section two we shortly describe the use of ubiquitous IT in SCM, existing approaches like EPCglobal and related work. The next section comprises our proposal for an architecture based on the Peer-to-Peer (P2P) paradigm. This architecture is then discussed concerning conceptional requirements especially of SME. Further on, a preliminary prototype is presented and tested by means of computational simulations. Finally we conclude with key findings, recommendations, limitations of our work and an outlook to further research.

2 BACKGROUND

SCM aims at the integration of business processes alongside the whole supply chain in order to increase global competitiveness through flexibility and responsiveness (Bowersox & Closs & Cooper 2007). Information systems play a major role for the integration across the supply chain (Gunasekaran & Ngai 2004). The deployment of RFID supports real-time, ubiquitous monitoring of the integrated supply chain, by making item-level information, e.g. product history and whereabouts, visible for all participants (McFarlane & Sheffi 2003). Other ubiquitous IT like environmental sensors or embedded

systems allow for even richer information services alongside the supply chain, e.g. cold chain monitoring or self-routing packages.

2.1 Supply chain RFID systems

An RFID system commonly consists of three components: Transponder (tag, label), reader and a backend system. A globally unique identifier for item-level identification of physical supply chain objects is needed to allocate information related to individual objects (Främling & Harrison & Brusey 2006). The Electronic Product Code (EPC) builds the identification foundation of the EPCglobal framework. It is an identifying code for objects tagged with RFID, similar to the traditional EAN for barcodes, but on item-level instead of object-class-level. The EPC consists of a header, filter, partition, manager master number, object class and serial number. The first three parts contain format and processing information (e.g. format type and length of object class number). The manager master number indicates the tag owning organization. Each organization that wants to use EPCs on its products has to acquire a master number. In the US and in Europe the EPC is the commonly used identifier. Other identifiers for item-level RFID concurrently were developed and are also in use (e.g. uCode in Japan).

Because memory capacity on tags is limited, extensive information is stored in backend systems connected to the RFID systems by networks (Diekmann & Melski & Schumann 2007). Through RFID-based information services business partners can immediately inform each other about any supply chain event information (e.g. "Packet 88 was shipped in Honolulu at 12:31 UTC") at time of occurrence and on item-level. Business process information flows can thus be automated, enabling supply chain participants to react to events in near real-time.

To allocate new or unknown services or look up changed service interfaces, the network system has to provide service discovery functions. The EPCglobal infrastructure provides core services to paying members of the EPCglobal network. One of the core services is the EPC Object Name Service (ONS) root. This service is administrated by the company VeriSign and is needed for search of EPC Information Services (EPCIS) offered by other participants of the network. The ONS root links address entries, by leveraging Internet Domain Name Service (DNS), to the manager master number of the organization, which provides the EPCIS. The holder of the master data number may operate local ONS and hierarchically link to further EPCIS or ONS. Non-certified EPCs or object identifiers of different formats cannot be processed by the EPCglobal network. Another core service is the Discovery Service. It is not completely specified yet, but will allow for search on item-level in the future. All core services are implemented and controlled by central authority of the EPCglobal organization. Disadvantages of the hierarchical structure and the centralized implementation of EPC core services are limited scalability and expandability, bottleneck and single-point-of-failure problems, unbalanced loads in the network, disabled self-organization and participants' loss of control and power. The characteristics of the EPCglobal architecture may be one reason for low adoption of RFID supply chain systems. Companies refuse to join the exclusive club and to pay fees while the system still is in development (Kürschner et al. 2008).

Efforts of EPCglobal and others are under way to improve and amend the framework. An open RFID service discovery with an alternative EPCglobal-like ONS root was brought up by Afilias for discovery of participants' local information services. Fabian and Günther (2007) elaborate security issues of EPCglobal and recommend geographically distributed name services. Other approaches bypass EPCglobal's network by developing completely new frameworks. One of those is DIALOG, in which identification of objects follows the scheme ID@URI (Kärkkäinen & Ala-Risku & Främling 2003). Here the address (URI) of information resources is deposited directly on the object's tag. This approach is quite flexible, but requires additional procedures for tagging, memory capacity on tags and administrating information resources stored at the URI.

2.2 RFID systems based on Peer-to-Peer networks

Requirements on scalability and efficiency of interorganizational RFID systems inspired efforts to create distributed solutions which support real decentralized coordination. Decentralized coordination is regarded as the more appropriate way to face challenges of managing complex supply chain processes in dynamic environments than centralized coordination (Amaral & Uzzi 2007). The concept of P2P networking is aligned to decentralized coordination in large networks of participants, who interconnect to exchange resources (Schoder & Fischbach & Schmitt 2005). Advantages of P2P systems for interorganizational applications are scalability, reduced risks of central bottlenecks, direct transactions, self-organization and failure resistance.

A special type of P2P networks, called structured or Distributed Hash Table (DHT) -based P2P networks, relies on hash table based communication protocols, which can guarantee efficient scalable and reliable information exchange (Risson & Moors 2006). In DHT-based P2P networks each information resource is stored as a key-value-pair and can be looked up with the key, which is an identifying name of the information resource (e.g. a file) mapped to a keyspace. Responsibility for the key-value-pairs is distributed fairly among peers. Each peer is responsible for a specified range of key-value-pairs and stores an address table with a confined number of known peers (neighbors) for routing purposes. Requests for storage or looking up of information are handled by routing those to a neighbor peer, whose hashed identifier is closest to the key in the keyspace. By this means it is ensured, that requests reach the responsible peer after a deterministic number of steps. Joining and leaving of peers is handled dynamically through intelligent repair mechanisms of address tables.

Summing up the current state, interorganizational RFID systems are centralized or proprietary and bear risk of performance weaknesses. Trying to face this, Wakayama et al. (2007) presented a product tracing system, which combines information service discovery using DNS according to EPCglobal with DHT-based service discovery. The major weakness of their approach is the chain-linking of address entries. If participants are not available, chains are broken and information can thus not be retrieved properly. Therefore, pursuing their idea, our architecture aims at efficient routing of information within a self-organizing, scalable, fully decentralized network of autonomous peers, without chain-links.

3 PROPOSED DESIGN OF THE P2P ARCHITECTURE

In this section we specify the design of our P2P architecture for service discovery of ubiquitous IT-based information services provided by participants within supply chains. We start with the description of object identification based on EPC or other identification schemata. Then we will illustrate the processes of providing and of querying information within the network. Lastly we explain the interoperability with EPCglobal.

3.1 Object identification

To identify an object tagged with RFID, a unique name has to be stored at the RFID tag memory. For RFID-based identification of objects the EPC provides a standardized name schema. For an open approach we regard it necessary to include any variants of identifiers in use or desired by applying companies, for instance hardware serials on RFID tags. A hashing function allows the publishing of information assigned to an object by using the hash value of any kind of object identifier. The hash value is mapped to a distinct location (one responsible peer and a predefined number of replication peers) in the network, from where participants can retrieve the entry directly by lookups using the object's identifier as search key. Object identifiers and participants' service addresses can be treated separately and multiple address links can be linked to one identifier.

3.2 Providing information to network participants

All RFID-based information generally remains in the participants' local systems. Only meta-information is made publicly available through stored entries in the network. Two main entry types are distinguished: *PublisherProfiles* and *PublicationRecords*. A *PublisherProfile* defines the interface for an information service of a participant, who provides object information for other participants. It consists of the type of service (e.g. SOAP or EPCIS) and the service address (e.g. URI of the SOAP internet interface). Once an object identifier was captured by a company, it may publish information on that object within the network. For each object there is one *PublicationRecord* stored in the network. A record comprises a list of *RecordEntries*, and each *RecordEntry* consists of a reference to a *PublisherProfile* and optional information about the entry (e.g. type of event). Optional information is time of the capture event, object identifiers (children) that were aggregated to this object identifier (e.g. a container), a parent identifier, and additional, unspecified data. Each *PublisherProfile* and each *RecordEntry* has an expiration time, after which it will be deleted to prevent the network from storing too much or outdated data. Figure 1 shows classes and attributes of publication data, which is stored in the network. The segregation of profiles and records allows for separate update of each. In SCM systems records are potentially updated much more often than profiles. Furthermore, additional certificates or other authentication and authorization data may be stored in the profile.

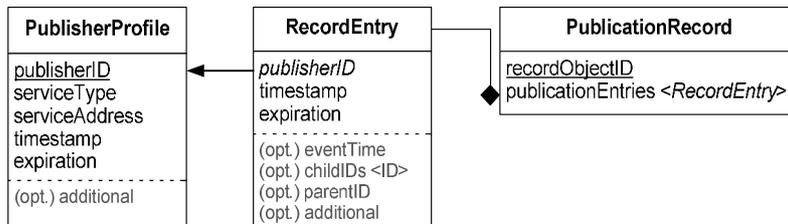


Figure 1. Main classes and attributes for data stored in the network

A participant who wants to provide information sends a *RecordEntry* together with the object identifier to the P2P network. It will be replicated (depending on the configuration of the peers) and stored in the network. The participant's profile will be published if it had not yet been published in the network or if he wants to update it.

3.3 Discovery and query of object information

The search for information is either accomplished directly with object identifiers or indirectly with queries, if a relevant identifier is unknown respectively is sought for or if other attributes are relevant for the search, e.g. date of entries. Direct search is simple and can efficiently be carried out in a DHT-based P2P network by taking the object identifiers as keys and looking up the keys in the DHT-keyspace. In contrast, complex query processing in P2P networks is a challenging task. Because in a fully decentralized DHT-based P2P network there is no participant who knows the entire network, an indirect query without an identifying key has to be resolved using distributed indices (Harren et al. 2002). If complex queries should be supported, indices have to be updated subsequently to each publication or periodically.

In addition to query processing the network also offers a publish/subscribe mechanism to realize event driven supply chain management. Information can then be pushed to interested participants immediately after capturing it. The mechanism allows participants to create a topic, subscribe to a topic or publish information linked to a topic, which automatically is sent to all subscribers of that topic. The topic subscriber group is also used for access and publishing restrictions by password.

Technically a topic corresponds with a sub-network of subscriber peers, which is in the same way self-organizing as the basic P2P network.

3.4 Interoperability

The proposed architecture offers interoperability with other systems like the EPCglobal network or ERP systems. Information to be published just has to be linked to any kind of object identifier and the publishing participant has to have or create a PublisherProfile. This means, the participant has to operate an information service at an address that is reachable by his supply chain partners. Figure 2 shows the components of the proposed architecture and how it could interoperate with EPCglobal. RFID reader events are processed by reader systems and middleware (which are provided e.g. by ERP software vendors) and then passed to our system as either binary data stream, XML or through data bases like MySQL. The system then extracts meta-information and publishes it in the DHT-based P2P network. On the other side, a query application can directly lookup meta-information of an object identifier or query meta-information through complex queries by sending a RecordEntry, where all determining attributes (e.g. event time) are filled and sought attributes are left blank. It then receives PublisherProfiles of participants which provide the appropriate information. By calling the service address given in the PublisherProfile, the query application can finally retrieve the information, e.g. from an EPCIS.

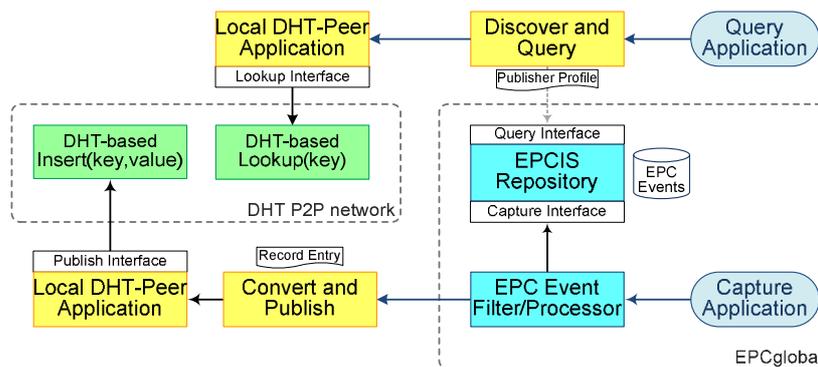


Figure 2. Components of the architecture and its interoperability with EPCglobal

4 DISCUSSION OF CONCEPTIONAL REQUIREMENTS

Conceptional requirements on supply chain RFID systems are manifold, depending on application context, supply chain and individual company needs. A detailed discussion regarding EPCglobal can be found in Kürschner et al. (2008). SME play a major role in implementing integrated supply chain RFID systems. On the one hand, as manufacturer, assembler or supplier of (pre-) products SME are in charge of tagging objects with RFID and of providing item-level information first (Gaukler & Seifert & Hausman 2007). On the other hand, SME can often act and operate very flexible, because of lean processes and organizational structures. Therefore, good alignment with innovative ubiquitous IT systems is attainable for SME. Despite that, SME still hesitate, e.g. in Germany 2007 only 3 % used RFID, but already 18 % of large companies (Martzahl & Renner & Pols 2007, p. 32). The following discussion will shed light on requirements of users, with focus on SME.

4.1 Scalability

Internet DNS root server process up to 48 billion queries per day (VeriSign 2008, p. 4). Upcoming item-level information systems will impose significantly higher volumes of information and queries. Furthermore, analogue to the Internet, benefits from RFID increase with amount of users due to

network externalities (Curtin & Kauffman & Riggins 2007, p. 95). Scalability is therefore most important for supply chain RFID systems. It ensures that companies are not restricted but can extensively interact with many business partners. Strong partnership networking is especially crucial for SME.

Based on DNS EPCglobal is organized hierarchically, and it is arguable whether centralized core services (like ONS root and discovery service) are capable of managing future loads. In a DHT P2P network there is no central bottleneck and with hashing algorithms information load is distributed equally. The search for entries with a DHT lookup receives a guaranteed answer even at high number of participants and communication loads. Also a limited response time can be guaranteed. Responses to searches and complex queries either contain the requested information (i.e. the appropriate PublicationRecords) or a *Null*-answer, if no one yet has published the sought information. DHT protocols like CAN, Chord, Pastry or Tapestry process lookups within $O(\log N)$ steps in networks with N peers (Risson & Moors 2006). The required address tables for routing the lookups only occupy $O(\log N)$ storage space.

4.2 Security

Access to and authenticity of supply chain data, which participants insert into the network, should be secured. In centralized systems security mechanism can easily be implemented through authorization of participants and control of data by the authoritative organization. On the other hand, the central authority may abuse its power, because it can take over control about data streams and network access. Furthermore, it is an obvious target for attacks.

In distributed systems other security means are feasible. Authorization can be realized by a public key infrastructure (PKI) and a trusted third party, which offers and validates certificates of participants. An alternative solution is the web of trust (Datta & Hauswirth & Aberer 2003), where authentication of participants is confirmed not by a certifying authority but by other participants. Furthermore, data should be encrypted and transported over public infrastructures via secure protocols like SSL.

DHT-based P2P networks are self-organizing and therefore capable of self-healing after dynamic joinings and leavings of participants or other disturbances - up to some degree (depending on the configuration e.g. of replication mechanisms). Within the networks there is no single point-of-failure, which would be a potential target for internal or external attacks. As long as there is no large group of malicious actors, the network is robust. Besides that, all peers are autonomous and have equal power and control over their own data.

4.3 Flexibility

Existing IT infrastructures of SME may not be well equipped, which hampers exploitations of RFID benefits, e.g. because information is not utilized to advance internal information processes. Therefore solutions should be flexible and allow for customized implementation. Dynamic business relationships and supply chain structures should also not be absorbed by static network structures. The ability to quickly respond to changing situations is notably essential for SMEs.

Most interorganizational RFID systems are bind to fixed structures, like the hierarchical infrastructure of EPCglobal, and to special naming schemata for object identifiers, like EPC or ID@URI. But dynamically changing business environments and especially the internal flexibility of SME, e.g. in adapting to customer needs, require flexible systems. Therefore, our network is not bind to any fixed structure. It is capable to handle dynamic groups of participants, and any character string may serve as a key for information provided within the network. For instance, serialized data from XML documents can easily be exchanged in the network. In this way, existing e-business standards (like AS2, ebXML, eCI@ass) can be included with small efforts. This allows for individual configurations by participating companies when they implement such a system and integrate it into their existing SCM or ERP

systems. The absence of a hierarchical structure supports flexible connections and enhancements. A distributed P2P system as proposed may be operated as a sub-network or a separate private network. In contrast, the EPCglobal architecture requires the establishment of dedicated instances, which operate core services and ensure unique naming.

4.4 Autonomy

Often SME are exposed to the power of major customers, who put pressure on them to implement systems suiting only customers' needs. In the past years large companies, for instance Wal-Mart, mandated suppliers to adopt RFID (Soon & Gutierrez 2008). But sustainable adoption of ubiquitous IT will only be successful, if a company has internal motivation. Provided solutions should support SME in using RFID independently from others. This, of course, holds true for all other companies as well.

The participants of a P2P network are independent from each other and from any organizing instance. There is no central server, whose breakdown would block network transactions or become a bottleneck reducing efficiency and scalability. It is nearly impossible for individual instances to gain control over the network. Costs of implementation and operation of the systems are fairly distributed among all participants. There is no fee which has to be paid to an infrastructure operator. To lower the barriers, an interorganizational RFID system should allow for lean and incremental implementation. It should not cause or intensify dependencies on other organizations. Participants of EPCglobal are bind to the core service infrastructure, which is operated by a commercial US company (VeriSign), as well as to the hierarchical network and fixed data structure. Our architecture is compliant with EPC standards and can be used in combination with EPCglobal or other systems, but it is not bind to the EPC.

4.5 Costs and benefits

Major barriers for adoption of RFID are high investment expenditures and unclear benefits (Angeles 2005). Many cost-benefit-analyses are concentrating on costs of RFID tags and readers - but costs for tagging procedures, process reengineering and reorganization, system integration and user training have to be taken into account (Smith & Konsynski 2003). As manufacturer or supplier SME suffer from cost-benefit-asymmetry, because they bear the costs of tagging, while large retailers take credit e.g. for better customer service and lower inventory. In addition, SME are deterred by the complexity of system rollout and integration. After employment of RFID systems the flood of information has to be managed and that often requires well-planned process reengineering. SME traditionally lack capital, time and competencies to accomplish these tasks successfully. Assigning consulting firms or service providers adds even more to the cost-side.

EPCglobal grounds on a complex framework, initially driven by interests of retailers and large corporate groups. Each participant has to pay a periodic subscription fee. In contrast, an open P2P network will be free of charge, because there is no authority to charge it. Despite that, adoption costs and benefits are hard to be determined, because they strongly depend on individual design choices and organizational factors (Dutta & Lee & Whang 2007, p. 646). But within complex supply chains a P2P-based solution encourages a fair approach.

5 SIMULATION-BASED ANALYSIS

Supply chains are complex systems, whose investigation is known to be difficult in many respects (Harrison 2007). Under these circumstances computational simulations provide a good method for the study of supply chain systems (Terzi & Cavalieri 2004). Our simulation-based analysis may set an initial point for subsequent empirical studies. By this means we can test the large-scale performance of our P2P system with affordable efforts. After shortly explaining the prototype and setup we will discuss selected results.

5.1 Prototype

The prototype is based on the generic DHT-protocol Pastry (Rowstron & Druschel 2001a), which allows creation of a P2P network as a self-organizing, fault-tolerant overlay in the internet. Pastry routes messages between peers based on a 128-bit hash-value ring provides load balancing and leverages peers' routing distances in the underlying internet for improved efficiency. Furthermore, we deploy the Pastry application PAST (Rowstron & Druschel 2001b) for hash-based, distributed storage and retrieval of data in Pastry networks. The prototype is implemented in Java and uses the open source Pastry implementation FreePastry¹. In addition to the direct search with hashed object identifiers we added two exemplary types of queries: (1) Entries published by a specific participant, and (2) entries of a specific date.

5.2 Simulation setup

The simulation is conducted with a network of N participants. After bootstrapping the participants stochastically publish RecordEntries. Each participant publishes his PublisherProfile at first entry publishing. The probability of publications per preconfigured time interval *interval* is defined by a parameter p_{pub} . Participants search (based on hashed EPCs) and query information in the network stochastically with probability p_{look} per interval. When receiving answers, they also lookup PublisherProfiles of received RecordEntries.

To examine the ability of flexible self-organizing, we introduce dynamic factors. The probability for leaving and joining of randomly picked participants is given by p_{join} and by p_{leave} . The parameter *rep* determines the number of replications which are stored for each entry in the network.

In each simulation experiment we measured the actual dynamics *dyn* (numbers of participants leaving and joining the network per interval), the actual number of activities *act* (publications and lookups) per second, and failures *fail*, and the average time till responses t_{resp} (excluding failed ones) in seconds. A publication or lookup activity is counted as failure, if there is no respond from the network after a preconfigured timeout (default 30 seconds). A Null-answer is not counted as failure, but as correct response.

5.3 Selected results

During the simulation runs we varied the input parameters for network size, replication, publishing and querying, joinings and leavings. The default time interval was set to 100 milliseconds. We run each experiment with at least 200,000 activities. Table 3 shows some selected results.

There were no significant differences in response times in different network sizes. The responses took 0.27 to 0.63 seconds on average. Moreover, failure rates were not significantly higher in larger networks. In small networks, e.g. with 500 participants, no failures appeared. Failure rates in low dynamic networks did not exceed 0.007 %. In networks with dynamics of 5 % of peers joining or leaving each minute failure rates increased slightly, but only up to 0.013 % (experiment 7 in table 3). The replication factor naturally had an impact on failures. On the one hand, more replications led to lower failure rates, down to 0 %. On the other hand, more storage capacity is used. But no observable influence on response times could be observed. Storage size for records ranged from less than 1 to a few 100 KB per peer. This obviously depends on amount and expiration time of published data. The used bandwidth for communication was not measured. Simulations of Haeberlen et al. (2005, p. 6) showed that the general overhead for Pastry consumed a bandwidth of 1-10 KB/s at maximum.

¹ The software version is 2.0_04, downloaded on 26 May 2008. Online: <http://freepastry.rice.edu/FreePastry/>.

	N	rep	dyn	act	t_resp	fail
1	500	0	4.1%	3,303	0.38	0.000%
2	500	2	1.7%	18,507	0.32	0.000%
3	500	2	2.5%	6,110	0.36	0.000%
4	1,000	1	1.1%	2,077	0.42	0.005%
5	1,000	2	0.4%	925	0.52	0.005%
6	1,000	2	3.8%	8,447	0.47	0.007%
7	1,000	2	5.0%	7,072	0.58	0.013%
8	1,000	3	4.2%	8,224	0.46	0.000%
9	1,000	10	2.7%	4,085	0.46	0.000%
10	10,000	2	0.5%	4,804	0.58	0.004%
11	10,000	4	0.5%	7,634	0.54	0.001%
12	10,000	10	0.6%	9,644	0.27	0.000%
13	20,000	2	0.3%	6,829	0.55	0.002%

Table 3. Selected results of experiments

6 CONCLUSIONS

6.1 Lessons learned

The challenge of implementing RFID systems alongside the supply chain is not trivial and the design of appropriate network architectures is crucial. This article aimed at proposing a P2P architecture to meet general demands for ubiquitous IT systems and some special requirements of SME. To overcome limitations of existing approaches we introduced decentralization of supply chain RFID systems. Good scalability and flexibility are major advantages of decentralized architectures. Sophisticated DHT protocols provide a highly efficient base for distributed supply chain RFID systems.

We illustrated our DHT-based P2P architecture and explicated conceptional requirements with special regards to SME. Further on we presented results of simulation experiments with our prototype for large-scale networks. The results indicated short response times and self-organizing capabilities to handle dynamic participant structures as well as prevention of failures.

6.2 Limitations

This work is still in progress. The prototype is no fully-fledged software and real-life tests still have to be conducted. Advanced security mechanisms are not implemented, but Fabian and Günther (2007) describe P2P-based security mechanisms, that can be applied for supply chain RFID systems. The proposed architecture is not meant to replace existing solutions, but to enrich and amend their further development. With our work we want to give design hints for more fair and scalable implementations.

6.3 Recommendations

Companies should thoroughly analyze available supply chain RFID systems before they start implementation. If they do not want to be dependent on global solution providers and to constrict their flexibility, decentralized architectures should be considered in particular. Nevertheless, technical standards like the EPC have to be taken into account for any interorganizational RFID implementation. SME without in-depth RFID knowledge can use support of consultancies and research institutes, but may keep in mind, that more scalable solutions provide more future potential.

6.4 Future research

Next parameters of the simulation model will be refined on the basis of empirical data taken from analysis of information and material flows in real supply chains. Empirical evaluation and scientific discourse are further steps of our research. With a refined simulation setup and an advanced prototype, we may predict future information flows within RFID-based supply chains and assess the suitability of different architectures more precisely. It is worthwhile to find out, how structures and dynamics of supply chain systems are affected by large-scale adoption of ubiquitous IT. Several alternative solutions will be available concurrently. It is necessary to pursue research on the design and quality of various solutions.

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