Discovery Service Design in the EPCglobal Network

Towards Full Supply Chain Visibility

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Abstract. The EPCglobal Network, an emerging standard for RFID, aims to raise visibility in supply chains by enabling interested parties to query item-level data. To get there, however, a critical piece is yet missing: a Discovery Service to identify possibly *unknown* supply chain actors holding relevant data for specific EPC numbers of individual products. Unfortunately, the Discovery Service architecture as initially conceived by EPCglobal needs revision as it either infringes the confidentiality of participating companies or its use is limited to identifying only participants already known. Against this background, this paper first discuusses the limitations of the architecture under consideration by EPCglobal and presents an alternative, more adequate Discovery Service design. Our concept encourages participation in the network while ensuring information provider confidentiality. Secondly, we present a roadmap for extending the existing EPCglobal Network with two critical services: an automated contract negotiation service and a billing service.

1 Introduction

Cost pressure in supply chain related processes has steadily been increasing over the last years. Hence, companies put much effort into reducing inefficiencies in the supply chain including incorrect demand and sales forecasting, low on-shelf availability, and inaccurate inventory levels [13]. However, the relevant information which can be used to overcome these problems is distributed among the partners within a supply chain [19]. Against this background, being effective and efficient in matching demand with supply requires a tight collaboration between supply chain parties [12].

Although collaboration promises mutual benefits for the partners, those benefits are rarely realized [20]. There are two critical issues to be overcome. First, in today's complex and dynamic supply networks, each company within the network has only partial knowledge about the participation of other companies. Hence, retrieving complete information regarding the flow of goods through the

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network requires high effort for locating all actors. Second, even if a company was able to locate all relevant supply network participants, there might be a lack of incentive to share sensitive operational data. Moreover, information sharing is usually based on contracts. Selecting and negotiating contracts is a non-trivial challenge for many companies and one common supply chain problem [25]. As a consequence, gaining sufficient transparency within a supply network coordinated by contracts cannot be established at acceptable costs and supply networks are bound to be inefficient and ineffective.

The EPCglobal Network attempts to solve this issue by enabling an interested party to find data related to a specific EPC number and to request access to these data. This infrastructure uses radio frequency identification (RFID) technology and leverages the Internet to access large amounts of information associated with Electronic Product Codes (EPC) [15]. A central component of this network realizing the abovementioned functionality is the Discovery Service which, according to EPCglobal, is to be mostly employed when it is "impractical to follow the chain" because participants are not known in advance [16]. In their current view, a client first contacts the Discovery Service with an EPC number. Then, the Discovery Service, based on the published records, replies with the owner of the information so that the client can directly contact the information owner for further details. Unless access rights accompany the published data within the Discovery Service, this has a privacy implication for the identity of the information owner is revealed irrespective of its decision to provide the information or not. On the other hand, maintaining access rights on the Discovery Service increases the software and management complexity. In addition, since these access rights can be strictly defined for known partners, this solution prohibits interaction with unknown organizations.

To counter this problem, our proposed new scheme makes the Discovery Service act as a proxy to forward a client request to the information owner. This solution, which we call the "Query Relay", allows for full access control at each organization. The information owner may reply with detailed information directly to the client or simply ignore the request, thus not revealing its identity. Furthermore, since the client request is relayed to possibly previously unknown partners, our complete solution envisages, besides the Discovery Service designed as described above, two more components. The first is an *automated contract negotiation service* whose role is to establish a one-to-one contract between two unknown companies stipulating the terms and conditions under which data can be shared. The second is a *pay-per-information pricing mechanism* that is supposed to give the information owner an incentive to provide its data, given it is financially recompensated. Nevertheless, note that the focus of this paper is on the architectural design of the EPC Discovery Service where we compare the design currently under EPCglobal consideration to our newly introduced "Query Relay". The two additional components mentioned above are only presented on a more conceptual level. In any case, the general emphasis is on the interaction among companies with no a priori knowledge about each other [16].

The remainder of the paper is organized as follows. In Section 2, we give an overview of existing discovery service concepts. We then present in Section 3 the requirement analysis, followed by the actual design solution in Section 4. Here, we compare the two Discovery Service design options – the original design as suggested by the EPCglobal or by the related literature and our own proposed design. Then, in Section 6, we describe how to enhance the EPCglobal infrastructure with an automated contract negotiation service and pay-per-information pricing. Our paper closes with an outlook on further research and a summary of our findings including managerial implications.

2 Related Work

A notable amount of research has been conducted in the area of discovery services. Alternative terms in literature are 'lookup service', 'directory service' and 'naming service'. In general, a discovery service provides a method for establishing contact between a client and a resource. A number of different approaches exist which vary according to the specific requirements they are designed to meet. In the following, we show that the existing solutions are not suitable for the EPC Discovery Service design.

The Domain Naming Service (DNS) is an essential component of the Internet [22]. It performs global discovery of known services / domains by mapping names to addresses. An assumption of this solution is that keys uniquely map to services, and that these keys are the query terms. Furthermore, all resources are publicly discoverable and access control is done at the application level rather than on the discovery service level [8]. But in contrast to Internet where domain addresses are freely available, EPC-related information needs to be protected and only selectively shared. The Domain Name Service is therefore not a good fit to build EPC Discovery Services.

Another example is the Service Location Protocol (SLP) which provides a framework to allow networking applications to discover the existence, location, and configuration of services in enterprise networks [23]. SLP eliminates the need to know the names of network hosts; only the description of the service is needed based on which the URL of the desired service is returned. However, SLP is not a global resolution system for the entire Internet; rather it is intended to serve enterprise networks with shared services, which makes it unsuitable for EPC Discovery Services. Furthermore, no authentication of an entity looking for appropriate services is provided. Finally, because access control is missing, confidentiality of service information cannot be guaranteed [8].

Last, but probably closest, are the first implementations of a Discovery Service in the context of supply chains done by IBM [6] and Afilias [2]. While the IBM demo represents a good start, showcasing the feasibility and usefulness of Discovery Services, there is no indication of a requirements-driven design. The Afilias prototype is more mature and the first to illustrate how security within the Discovery Service can be build. Nonetheless, they both follow the EPCglobal concept whose limitations will be explicitly addressed later in the present work.

3 Requirements Analysis

Based on interviews conducted with experts and end users, literature review and project work, we identified several issues that are highly relevant for the design of the Discovery Service and for the wide adoption of EPCglobal Network.

3.1 Data Ownership

From a technical standpoint, publishing data to the Discovery Service is readily defensible, particularly, when taking into account recent developments in information and telecommunication technologies. Technical considerations, however, represent only part of a more complex story in which less tangible issues play a critical role. That is, from an economic standpoint, data control aspects need to be considered. Our investigations show, that at least some companies are not willing to even share the EPC and the related EPCIS addresses with other companies.

It seems that local control can be optimal even when there are no technical barriers to a more centralized solution, like observed by Markus [21]. Key reason for the importance of data ownership is self-interest, that is, owners have greater interest in system success than non-owners. As a consequence, ignoring ownership aspects for system development might be a possible explanation for failures [26]. Based on this background, Davenport et al. state "No technology has yet been invented to convince unwilling managers to share information..." [9]. Today, some information is just too valuable to give it away. According to van Alstyne et al., we define data ownership as the right to determine data usage privileges to other companies and as the ability to track the actual usage [26].

Based on our findings, there are two requirements for the Discovery Service design in regards to data ownership. These are:

Requirement 1. *Companies shall be in complete control over their data including EPCIS addresses, read events, business data as well as setting of detailed, fine-grained access rights.*

Requirement 2. *Companies shall be able to track the usage or the requests upon their data. Particularly, duplications of data at the Discovery Service level should be avoided.*

3.2 Security

Security has always been a critical issue in distributed systems. In our concrete context, it becomes a decisive factor for the broad adoption of the EPCglobal Network. At the heart of the network, enabling the detection of information sources, the Discovery Service consequently demands for very strict security measures that realistically justify inter-company collaborations and data sharing.

The notion of a secure system is linked in the literature to that of dependability [18]. Simply put, a dependable system is one that we trust to deliver

its services. More specifically, dependability comprises availability, reliability, safety, confidentiality, integrity, and maintainability. Availability is defined as a system's immediate readiness for usage whereas reliability refers to the continuity of service over a prolonged period of time. Confidentiality expresses the property of a system to disclose information only to authorized parties. Integrity is the characteristic that prevents improper alterations to a systems assets. To ensure security, one needs to associate integrity and availability with respect to authorized access together with confidentiality [18]. While all of the above security features are essential, there are two requirements that stand out for the architecture of the Discovery Service. These are:

Requirement 3. *The confidentiality of both the publisher data and client query shall be ensured by the Discovery Service design.*

Requirement 4. *The Discovery Service architecture shall ensure a high overall system availability and reliability.*

3.3 Business Relationship Independent Design

Nowadays, the business environment is dynamic. Different customer demands, globalization, discovery of uncharted market opportunities, outsourcing, innovation and competition, the continuously varying technological landscape are just some of the major factors that determine significant partnering changes in supply chains. To that end, in order to increase their own strategic flexibility, many companies find changing supply chain partners simpler and also cheaper than changing internal processes [7].

To protect its data from unauthorized access, a company must define and maintain fine-grained, customized permissions for each of its partners. As soon as a company modifies its set of trading partners or simply its existing collaborations, it also needs to define access rights reflecting the new business relationships. We learnt from our investigations that companies want to minimize the access control maintenance effort. This leads to the establishment of an additional important requirement for the Discovery Service, that is:

Requirement 5. *Changes in business relationships shall not affect the way in which a company interacts with the Discovery Service.*

3.4 Organic Growth

One key issue of the EPCglobal Network is organic growth, that is, over time more and more companies will participate in the network and the data volume will increase. In this context, Rogers [24] stated that adopters of any new idea or innovation can be categorized as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%). Hereby, an adopter's willingness and ability to adopt an innovation depends mainly on their awareness, interest, evaluation results, and successfully performed trials.

Based on these findings, we have to be aware of the fact that initially only a few companies will be willing and able to adopt the EPCglobal Network. Over time, more and more companies will join, leading to a massive increase in data volume. Thus, supporting an organic growth is crucial for the design of the Discovery Service. Furthermore, as we stated before, the more companies of a supply chain or supply network take part in the EPCglobal Network, the more valuable it is. By lowering the threshold for joining the network for less innovative companies, we will be able to foster the adoption of the EPCglobal Network. Given the aforementioned aspects, we draw another important requirement for the overall Discovery Service solution.

Requirement 6. *The Discovery Service architecture shall encourage participation in the EPCglobal Network.*

3.5 Scalability

Another requirement is the scalability of the service. Scalability refers to the ability to handle large amounts of requests and data. Concretely, Discovery Services need to be able to serve queries of potentially millions of clients. At the same, time Discovery Services need to be able to store EPC numbers and links form EPCISs at the rate of new instances of products being produced. We expect the volume of EPC number updates to be several times the volume of client queries.

Requirement 7. *The Discovery Service architecture shall be highly scalable, able to handle the network traffic both in terms of data volume and number of participants.*

3.6 Quality of Service

The concept of fitness for use is widely adopted in quality literature. This concept emphasizes the importance of taking a consumers viewpoint in regards of quality [11]. When designing the Discovery Service, we need to consider the querying party's viewpoint of fitness for use, that is, return data that are suitable for decision making. Following information systems literature, user satisfaction and information quality are two major issues for the success of information systems [10]. In more detail, these two dimensions include specific concepts such as accuracy, timeliness, completeness, precision and relevance, as well as accessibility and interpretability [4] [17] [28].

Based on the above findings, the Discovery Service needs to be designed in a way that the companies that are requesting information about a certain EPC receive data of an appropriate quality. Our findings indicate that a complete and correct response are always relevant. This conduces to the following requirement:

Requirement 8. *The query result shall be complete and correct, respecting the client's access rights defined separately by each information provider.*

4 EPC Discovery Service Solution Concept

The EPCglobal Network is a collection of interrelated standards for hardware, software and data interfaces that aims at enhancing the supply chain through the use of Electronic Product Code (EPC) - a globally unique and standardized identifier contained in each RFID tag labeling a product. More specifically, the components of the EPCglobal Network provide the functionality to capture and share RFID information in today's complex trading networks [16].

The network consists of three main components: the Object Name Service (ONS), the EPC Information Services (EPCIS) and the EPC Discovery Service. ONS is the authoritative directory of information sources available to describe an EPC associated to a product - typically this is the manufacturer. EPC Information Services are the actual repositories at each company's site that store data about unique items in the supply chain. The EPC Discovery Service component is essentially a chain-of-custody registration service that enables companies to find detailed, up-to-date data related to a specific EPC and to request access to those data.

Next, we describe two different Discovery Service designs – the one considered by EPCglobal in Section 4.1 and our alternative design, the Query Relay, in Section 4.2. For the description of both designs, the following *assumptions* are made:

- The client is pre-configured with the service location of the Discovery Service to avoid bootstrapping related issues.
- Each information provider publishes EPC-related information to the Discovery Service in advance.
- The actual access to data is managed locally at the EPCIS where the company itself determines which trading partners have access to which information [15].
- The Discovery Service provider is a trustworthy entity that provides the service as described and does not misuse the data.

4.1 Directory Look-Up Design

We present here the Discovery Service design currently under consideration at EPCglobal. The description is based on the review of existing literature [2] [6] [14] [15] [27]. Figure 1 illustrates in detail the process of retrieving information related to a specific EPC. It is organized along the traditional client-server architecture. The concrete steps are:

(1) A company – hereafter referred to as *client* or *information requester* – asks for information about a specific EPC-equipped product. It sends its query request to the Discovery Service;
(2) The Discovery Service looks up all EPCIS addresses that hold data about the provided EPC number;
(3) The Discovery Service sends the related addresses back to the requesting company;

(4a) and (4b) The client queries the given EPCISs directly.
(5a) and (5b) The queried information providers A and B check the client's access rights;
(6) Given the client is authorized to get information, the query result is sent by the information providers. In our example, only Company B replies.

Some key observations: unless there are access control policies at the Discovery Service set by A, the information requester knows that Company A did not deliver any information and, moreover, the identity of Company A is revealed to the information requester. This might generally not be a desired effect. However, if access rights are set to the Discovery Service, we run into the duplication problem. Concretely, this means that control policies are published by Company A along with any data to the Discovery Service. Redundancies are thus created and the complexity of the data structures within the Discovery Service significantly increases.

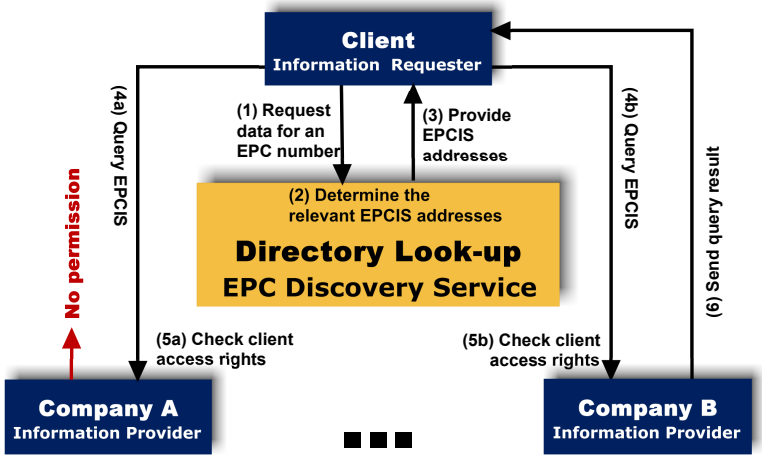

Fig. 1. Directory Look-up Design of the EPC Discovery Service. Note: initial publishing of records omitted.

4.2 Query-Relay Design

Based on the requirements presented in the Section 3, we suggest the following Discovery Service solution, as depicted in Figure 2. To the best of our knowledge, this design is innovative in the context of EPCglobal Network. We proceed by explaining every step of the querying process in detail:

(1) An information requester is asking for detailed information associated with an EPC;
(2) The Discovery Service looks up the relevant EPCIS addresses;

(3a and 3b) The Discovery Service forwards the complete query to the identified information providers;
(4a and 4b) The queried information providers A and B check finegrained access rights defined for the client;
(5) If access is granted, the query is answered directly to the querying company.

Some key observations: each company defines its access rights at the EPCIS level but does not duplicate these to the Discovery Service level. The Discovery Service only holds a list of EPCs and related EPCIS addresses. The main purpose of the service becomes now the routing of queries. Notice additionally, that the information requester does not become aware that Company A denied access to its information.

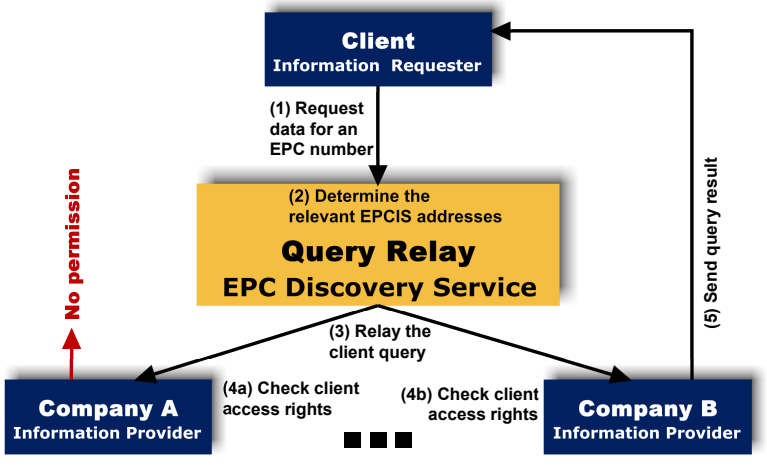

Fig. 2. Query Relay Design of the EPC Discovery Service. Note: initial publishing of records omitted.

5 Discussion and Evaluation

In this section we comprehensively compare the two suggested solutions. As evaluation criteria we use the identified requirements from Section 3.

Data Ownership. In the Directory Look-up solution, any published data must be accompanied by access rights at the Discovery Service. If companies fail to do so, they would leave their own published data open to any random client and, hence, lose control over it – a violation of Requirement 1. But even with access rights maintained and stored at the Discovery Service together with the published data, control is merely delegated to the Discovery Service provider. In this case, companies might still find difficult to track the requests upon their data within the Discovery Service. Besides, the access rights duplication problem remains unresolved and thus Requirement 2 is not met.

The Query Relay design, on the other hand, abides both Requirement 1 and 2. It is very lightweight, avoids heavy duplication and the data published within the Discovery Service is used for routing only. Nothing is ever returned to the client, whose complete access to the data is controlled directly and locally at the EPCIS of the information provider.

Security. First and foremost, the security of the Discovery Service must address the interaction between a publisher and a client and their prospective information exchange. For both of them, confidentiality correlated with availability and reliability of the system are the supreme necessities.

We first address publisher confidentiality. The Directory Look-up design ensures publisher confidentiality if and only if access controls are enforced within the Discovery Service. As already stated, these access rights must be adjunct to the published data; otherwise, the published identity / EPCIS address, together with any additional data contained in the published records for a particular EPC, could be freely revealed. In the Query Relay design however, the condition guaranteeing publisher confidentiality is less strict. Concretely, it is only required that the Discovery Service provider is trustworthy in the sense that it would not further disclose the published records. Hence, the part referring to publisher confidentiality of Requirement 3 is better satisfied by the Query Relay.

Second, we analyze client confidentiality. This mainly refers to unveiling the query itself. The information held within a query reflects the strategic intents of a client. This is considered sensitive information. In the Directory Look-up design, the client query is treated confidentially by the Discovery Service, in the sense that it is not passed further to EPCISs. This is opposed to the Query Relay design, where the client query is straightly forwarded to EPCISs, without the control of a client. These EPCISs might be malicious and thus the client is put at risk. However, a similar risk could be pertinent to the Directory Look-up design as well: once the client has received the EPCIS list, it may query potentially malicious information services not identifiable as such by the Discovery Service. Hence, the part referring to client confidentiality of Requirement 3 is satisfied in approximately the same manner by both designs.

Finally, we examine availability and reliability. These two properties, forming Requirement 4, are similarly fulfilled by both designs. More precisely, if the Discovery Service is down, no response at all is given to the client. We particularly consider the case where the client as well as the information providers have a transient connection to the network. The problem can be overcome in the Directory Look-up design by duplicating information providers' data to the Discovery Service level during uptime. However, this is rather unlikely as companies want to be in control of their data and, thus, are reluctant to duplicating data to a third party system.

Business Relationship Independent Design. As described previously, this requirement solicits that business relationships do not influence the way in which companies interact with the Discovery Service. In the center of attention are here the access rights again.

In the Directory Look-up design, there are two levels of access control: one on the EPCIS and another one on the Discovery Service. As the access rights encode a company's business relationship with its trading partners, any partnering changes directly trigger a modification in the access rights. Following the Directory Look-up design, this modification must be reproduced without delay both in the access rights on the EPCIS and on the Discovery Service. Maintaining permissions in this dual manner creates an additional effort, increases software complexity and even introduces a potential attack point as compared to the Query Relay design, where there is a single point of access control – at the EPC Information Service. Requirement 5 is consequently fulfilled only by the Query Relay design.

Organic Growth. To launch the EPCglobal Network in terms of partakers, the concept of *clusters* has been introduced. A cluster is an environment comprising only *trusted* business partners of a supply chain that are serviced by their own Discovery Service. With more and more companies interested to join the network over time, it is natural to assume that two or more clusters will merge. We now analyze how the two discussed Discovery Service models facilitate cluster merging. In the Directory Look-up, when opening up a cluster, at least some information, like published references to sources of detailed EPC data, is revealed to newcomers. As a consequence, before merging, there must be a unanimous and mutual consent on granting newcomers' permission to join from all the members of both clusters. Yet, this might be very hard to achieve because one or more companies within a cluster might identify competitors in the other cluster. Their data ownership concerns are thus significantly augmented. As a result, the evolution of EPCglobal Network is in fact hindered with the Directory Lookup approach. Contrarily, the Query Relay solution makes it easier for companies to join the EPCglobal Network anytime and, most important, companies already taking part in the network are not affected at all. If the established companies want to extend their network, they simply have to provide appropriate access rights locally on the EPCIS level. Any modification to these access rights will be immediately functional network-wide while allowing publishers to be in agreement exclusively with the Discovery Service provider. Requirement 6 is, as a consequence, much better fulfilled by the Query Relay design.

Scalability. Both designs do not address scalability directly but need to rely on additional mechanisms. The issue of client queries is slightly more accentuated in the Query Relay approach because queries need to be forwarded. On the other hand, the much more significant EPC number updates are handled equally in both design approaches and thus they are susceptible to the same scalability issues. Forwarding client queries can be seen as routing data (i.e., the query) based on EPC numbers contained in the queries. There exists a large body of work on routing high volumes of structured data (e.g., queries) in internet-scale overlay networks, particularly in the publish-subscribe and content-based routing research communities [1] [3] [5]. We believe that existing technologies suffice to cope with forwarding queries. Likewise, for handling and storing mass updates

of EPC numbers, suitable mechanisms exist and need to be identified. This is a top priority for future work.

Quality of Service. As mentioned before, data quality in the context of EPCglobal Network primarily refers to the completeness and correctness of query results. A query result might be incomplete or incorrect for either of the following three reasons: first, not every read EPC event has been internally stored in the information provider's EPCIS repository; second, the information provider has fabricated EPC events; and third, an information provider consciously denies access because the requested information is too sensitive.

The first two cases are nothing that a Discovery Service, independent from the chosen architecture, could combat. Achieving full supply chain visibility in these cases is compromised anyway. In the last case however, without exposing the information provider, the Discovery Service might assist the client with information whether the query result is complete or correct. For instance, it can inform the client of the length of the trace, i.e. the number of nodes containing detailed EPC information. Consider now the Directory Look-up design and, in addition, realistically assume that the information provider did not publish its sensitive EPC data to the Discovery Service. Unlike in Query Relay design, the Directory Look-up might allow a client to identify the information provider who did not answer. While this constitutes a slight advantage in regards to adjuvant information on completeness, on the negative side, from a security standpoint, this property breaches the confidentiality of the information provider. We can thus conclude that Requirement 8 is better satisfied by Directory Look-up at the expense of infringing information provider confidentiality.

6 The Complete EPCglobal Network Vision

In a competitive environment with numerous parties like the supply chain networks of today, cross-organizational collaboration and information sharing become fundamental. To appropriately support them, very strong security must be enforced at the level of the EPCglobal Network. Until now, the discussion within the EPCglobal working group or any related literature along security measures only refers to the definition of powerful access rights. The pure access rights are, however, not sufficient for enabling companies to interact with strangers – parties that are neither trusted nor distrusted, but just not recognized. This is because any company would define its access rights permitting another company to retrieve its operational data no sooner than the two of them have established a first contact. This is counter-intuitive to the general concept of EPCglobal Network, whose main purpose is to foster collaboration, independent of previous business relationships. Since interaction with alien partners is often unavoidable, sometimes even necessary, in today's increasingly dynamic supply chain networks, it should by no means be obstructed.

The arguments given above clearly point to several challenges that need to be overcome in the context of EPCglobal Network. First, all actors in the supply chain who were custodians of a product must be located. This includes both

known and unknown parties and lies under the responsibility of the EPC Discovery Service. Second, there must be a mechanism to mediate trust between two a priori unknown parties. For the known partners, the exchange of information is usually mandated by a one-to-one contract. Complementarily, for the unknown ones there should be a mechanism which negotiates the one-to-one contract automatically. This is a truly daring and intricate pursuit. Therefore, there must exist an incentive for this kind of dicey collaboration. In most cases, money constitutes a reasonable argument. This brings us to the third and last challenge, namely a system able to automatically bill the companies retrieving information. Most naturally, the billing takes the form of pay-per-information. To summarize, we envision the complete solution comprising the following three components. These three building blocks together with interaction between two companies – a client and a server – can be modeled as depicted in Figure 3.

1. **EPC Discovery Service.** The main purpose of the Discovery service is to locate all actors in the trading network who own information about an EPC of interest to the client.
2. **Automated Contract Negotiation Service.** The main purpose of this service is to replace or support the conventional paper contracts and human negotiation leading to the establishment of those contracts among the supply chain actors.
3. **Pay-per-information Pricing Model.** The main purpose of this service is to incentivize inter-organizational information sharing through financial recompensation.

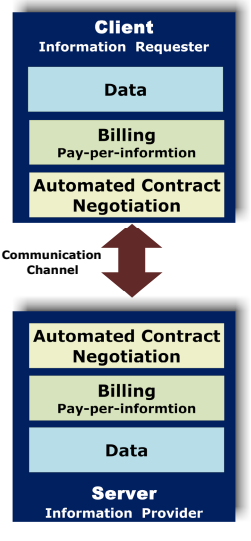

Fig. 3. Enhancements to the EPCgloblal Network at the EPCIS level: automated contract negotiation and pay-per-information pricing

The EPC Discovery Service acts as an enabler of the entire solution scope, including automated contract negotiation and pay-per-information pricing. There is a subtle yet significant difference between the two designs in regards to the extent a client query reaches the relevant information services holding information for an EPC of interest. In the Directory Look-up design, due to access rights which companies could justifiably store within the Discovery Service to avoid openness, a client query will never reach industrial parties not known in advance. In other words, only publishers that have explicitly granted access to the client can answer. This represents an impediment towards achieving full supply chain visibility, as it prevents interaction with strangers. Note that storing no access rights within the Discovery Service is *not* an option as it ultimately leads to the infringement of publisher confidentiality. On the other hand, with the Query Relay design, a client query reaches all relevant information services for an EPC. Thus, besides known partners, companies that are nothing but merely strangers to the client are also given the chance to provide information.

7 Conclusion and Future Work

In this paper we presented an alternative design for the EPC Discovery Service. This design was driven by the requirements we elicited from interviews and literature research. We identified five major requirements – data ownership, security, business relationship independence, organic growth, and quality of service. The discussion along these requirements showed that the originally suggested Directory Look-up Discovery Service design only partially complies. Most prominently, this design does not encourage participation in the EPCglobal Network even when clusters of trusted parties are formed and poses serious problems to publisher confidentiality. Against this background, we proposed a lightweight Discovery Service, the so-called Query Relay, that only stores the EPCs and related EPCIS addresses. When querying for more information about an EPC, the Discovery Service simply forwards the query to the relevant EPCISs. Access rights are checked only locally at the EPCIS level and the initial query is answered directly to the querying company. As opposed to the Directory Look-up, no data – including access rights – need to be duplicated to the Discovery Service level. By having such a design, companies will be in complete control of their data. In effect, we create a significantly more secure solution, lower the threshold for companies that want to take part in the network and, thus, support an organic growth. Above all, the Query Relay design makes it easier for a client to deal with parties unknown a priori, which increases the chance to attain full supply chain visibility. In this respect, we envision an automated contract negotiation service incorporated in the EPCglobal infrastructure. Additionally, a pay-per-information pricing model might be supported as an incentive for the information provider to share its operational data.

We see potential for further research in several directions. First of all, in the Query Relay model, the development of a more selective and intelligent routing of client requests is desired. This can also have a security benefit since

client requests are not disseminated further than necessary, compromising the confidentiality of the client. Mechanisms to enforce the registration of accurate routing data will be an essential research area, especially since it will be hard to detect if an EPCIS has published correct routing data to the Discovery Service and simply refuses to respond, or if it cannot respond because it has published inaccurate data. Second, it is crucial to precisely assess the scalability of both Discovery Service designs. Third, the challenges related to incompleteness of the query result need to be examined. Finally, an equally important matter is the standardization of EPCglobal interfaces which may need to be tailored to suit our proposed solution, particularly addressing the automated contract negotiation. As automated negotiations typically follow an offer-counteroffer workflow, it is interesting to inspect what could be simple yet reliable offers / counteroffers in our environment.

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