Architecture-Based Hierarchical Interoperability Modeling and Evaluation of Internet Systems

Fande Yang, Huabing Han, and Song Wang

***Abstract*—Internet-based information systems are usually built upon unified information model and standard protocols. Interoperability can be defined at various layers from infrastructure to platform, to information, and to applications. The paper analyzes the interoperability requirements of information systems in the Internet architecture. It identifies interoperation elements for different layers of the information systems, and ranks the capability into levels and sub-levels. Interoperability evaluation based on the capability framework is transformed to a decision making problem. The paper introduces a systematic calculation process following Analytical Hierarchical Process (AHP) and Analytical Network Process (ANP) method.**

***Index Terms*— Interoperability, Interoperability Framework, Interoperability Evaluation, Internet-based information system**

I. Introduction

INTEROPERABILITY is defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [1]. For Internet-based information systems, interoperability is usually built upon shared data and information models, and standard communication protocols. Interoperation is thus achieved through multiple layers including the communication infrastructure, information exchange platform, and application interoperation. Fig. 1 shows a general architecture of the interoperation of Internet-based information systems.

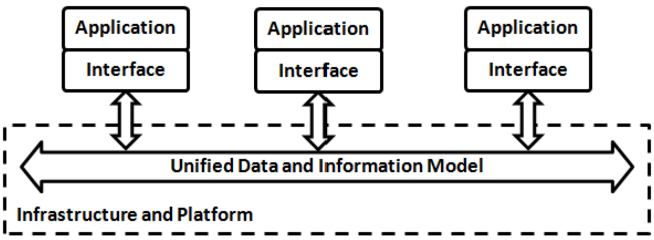

Fig. 1. A general architecture of Internet-based information systems. Interoperation is achieved at different layers from infrastructure to platform, to data model, and to application. To exchange information among application, a unified data model is necessary for application communication and interoperation. Application will access the model and the infrastructure through standard interfaces.

Interoperability evaluation a critical yet challenge problem of Internet-based information systems. Various models have been proposed to categorize and rank system interoperability qualitatively. LISA (Levels of Information Systems Interoperability), proposed by C4ISR architecture working group, is one of the widely used reference framework for defining, evaluating, and measuring system interoperability [2]. It uses four properties to evaluate interoperability including: the Process (P), such as technical standards, architecture, policy, and regulations; the Application (A), such as the software for information exchanging, processing, and management; the Infrastructure (I), such as system services, communication protocols, remote procedure calls; and the Data (D), such as the storage, format, and semantic of application data. For each property, it defines five levels ranking from low to high as isolated, connected, functional, domain, and enterprise. NC3TA (NATO C3 Technical Architecture Reference Model for Interoperability) [3] defines a group of standards, architecture and reference models. It focuses on the evaluation of system capability of automatic exchange and interpretation of well-defined structural data. Tolk [4] pointed out the importance of conceptual interoperability model and proposes LCIM (levels of Conceptual Interoperability Model). LCIM defines 7 levels of interoperability from level 0 to level 6 including no interoperability, technical interoperability, syntactic interoperability, semantic interoperability, pragmatic interoperation, dynamic interoperability, and conceptual interoperability. The highest level, conceptual interoperability, requires "fully specified, but implementation independent model".

Most of current models tried to define a generalized framework so that it can be applied to various types systems, and can cover as many aspects as possible from technique to organization. However, Interoperability is closely related to system architecture. The interoperability of a information system is decided by the capability of all its constituent components and supported environment. Hence, this paper attempts to establish a targeted interoperability model for internet software architecture. Following JCIDS (Joint Capabilities Integration Development System) methodology [5], it identifies three key elements of interoperability requirements, system environment, and standards, and builds the analysis framework. Based on the analysis of internet architecture, it abstracts the system into 4 layers and defines interoperability ranking of each layer. The hierarchical interoperability model is then measured quantitatively following the Analytic Hierarchical Process (AHP) and Analytic Network Process (ANP).

The rest of the paper is organized as follows. Section II proposes the architecture-based hierarchical model of

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Fande Yang is with the Academy of Equipment, Beijing, China, 101416 (corresponding author, e-mail: yangfd5908@sina.com).
Huabing Han is with the Department of Computer Science and Technology, Tsinghua University, Beijing, China, 100084 (e-mail: hh4094408@163.com).
Song Wang is with the Academy of Equipment, Beijing, China, 101416.

internet-based information systems. It introduces the analysis methodology and framework, analyzes interoperability requirements of Internet-based information systems, and proposes the reference model for interoperability ranking. Section III describes the evaluation process and methods. Finally, section IV concludes the paper.

II. Interoperability Modeling Based on Internet Architecture

A. *Interoperation Requirements Analysis*

Internet-based information system is usually built from complex architecture, composing large number of third party components using various technologies. The loosely-coupled internet software architecture provide a flexible and efficient solution for large-scale software development in distributed heterogeneous environment. Hence, a system is built by composing components with standard interfaces, through a middleware platform. To ensure interoperability among collaborated components, a unified data model usually lies in the central of the architecture for content mutual understanding, as shown in Fig. 1.

Through a careful analysis of system architecture, we define interoperability at different layers. C4ISR is a typical hierarchical model of network system. Motivated by interoperation requirements, this paper proposes a 4-layer hierarchical model for interoperation analysis, from infrastructure to user-oriented applications.

1) Application layer. Interoperation is achieve by composing different business process and sharing information among applications. Interoperability problems are usually caused by the diversity of workflows.
2) Information exchange layer. Interoperation is achieved by well-defined data structure, format and semantics. Some domain-specific conceptual models can be built as a standard for automatic information processing and understanding. Interoperability problems usually result from inconsistent data models, including syntax and semantic definitions.
3) Platform layer. Platform provide system services to support upper layers of data and applications. The quality of the platform (such as efficiency, compatibility, salability, and so on) has a serious impact on the upper layer applications. The incompatibility between heterogeneous platforms is a common problem of system interoperability.
4) Infrastructure layer. Infrastructure provides the necessary network connections and communication protocols. For system interworking, the connectivity among physical instruments and the compatibility among various protocols are the basic requirements.

B. *The Analysis Framework*

JCIDS is proposed to address the shortfalls of traditional demand generation system of electronic information system. By conventional approach, requirements are driven by separated views of risks; while JCIDS enforces a joint perspective so that all the systems can be built in the context with all the services into consideration. JCIDS makes system born with connection capacity to solve problems in system interconnection, information interflow, function interoperation from the beginning of system development. In this way, it can avoid superfluous overlapping systems and enhance system operational interoperability.

The paper follows JCIDS analytical methods and processes and identifies three key elements of interoperation analysis: *Interoperation Demands*, *System Environment* and *Standards*. Driven by the demands, it aims to provide a reasonable framework of the necessary capabilities for analyzing and evaluating system interoperability.

Elements of *Interoperation Demands* determine the capacity development requirements for interoperability. Elements of *System Environment* provide system support to achieve interoperability, which determine the intra-node and inter-node mutual connection relationships of system nodes, the system, and system components nodes. Elements of *Standards* generate the corresponding technical standards according to the required capacity provided by system environment. Fig. 2 shows the analysis method.

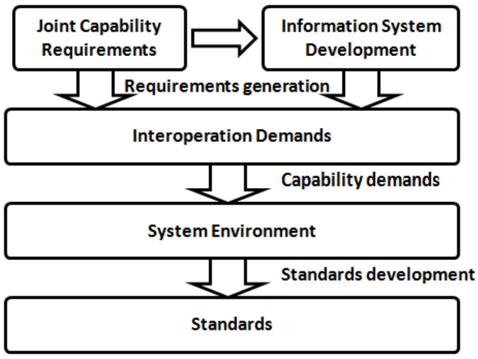

Fig. 2. The analysis method and process. Interoperability framework is composed of three elements: *Interoperation Demands*, *System Environment*, and *Standards*. Following JCIDS methodology, requirements are generated based on joint capability analysis.

The three elements are analyzed at each layer of the interoperability architecture, as shown in Fig. 3.

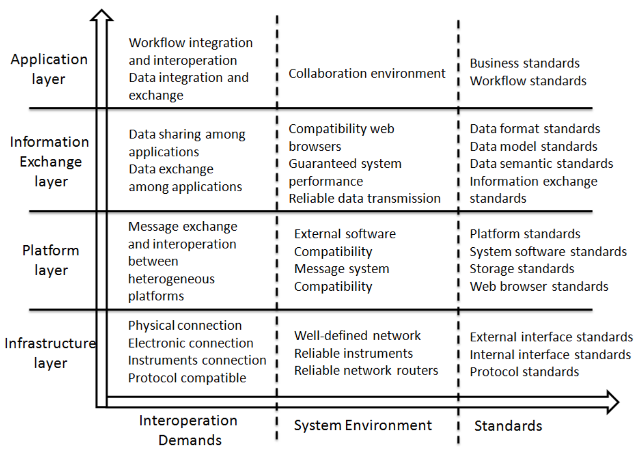

Fig. 3. The analysis framework. The 4 layers of the interoperability framework are analyzed from three aspects following the analysis method. At each layer, for each aspect, a set of elements are identified for interoperability analysis.

C. *Capability Model*

System in different domain and context may require

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different levels of interoperability. For example, in one scenario, information exchange between nodes only require simple transmission of informal voice and text data. In another scenario, it may require more refined and well-defined information exchange, such as multiple distribution media information; the participants need to collaborate in a shared space; and multiple organizations need to jointly make decisions. Hence, a reference framework is necessary to define a formal structure for characterizing the complexity of information exchange into different levels.

Table 1 shows the reference capability model. It ranks interoperations at each layer into 5 levels, including:

1) Level 0 – Isolated. No interconnections (physical and electronic) between systems. Information exchanging is manually using floppy disk, hard disk, CD, or even paper documents.
2) Level 1 – Connected. Physical and electronic connections have been established for simple information exchange. Systems interact using simple homogeneous information such as voice, email with no attachment, graphics.
3) Level 2 – functional. Distributed systems can interoperate in a LAN environment to exchange complex homogeneous information, such as multi-media data and electronic map. A unified conceptual model is defined to be shared among systems.
4) Level 3 – Domain. Systems in an integrated WAN environment can interoperate. Heterogeneous generous information can be shared among various applications. A domain-specific unified data model is defined to enable database-to-database information exchange.
5) Level 4 – Cross domain. Information and applications can be shared between applications across different domains.

TABLE I
EXAMPLE OF THE MULTI-LAYER MULTI-LEVEL INTEROPERABILITY CAPABILITY MODEL

Interoperation levels		Interoperation Layers			
		Infrastructure	Platform	Information Exchange	Application
Level 4 – Cross Domain	c	Multi-dimensional topology	Interactive system software	Shared data model and data dictionary	Cross domain, interactive application
	b				
	a				Full object cut & paste
Level 3 – Domain	c	Wide Area Network	Shared system software	Object-Oriented database	Shared data, direct data exchange between databases
	b			Unified data model	Group collaboration
	a				Full text cut & paste
Level 2 – Functional	c	Local Network	Network services, generalized interface services	Application data model Information exchange require protocol change	Data sharing and transmission based on network storage
	b		Operation system services, graphic browser, data management services		Information exchange requires addition services to read, write, and process the data from different systems.
	a	Broadcast Network	Complex message middleware		Complex message (e.g. email with attachment)
Level 1 – Connected	d	Bi-directional connection	Security service, conforming to corresponding standards	Basic data format (homogeneous data product)	Basic message type and format
	c				File transmission through external network
	b				Simple interaction
	a	Unidirectional, compatible external interface			
Level 0 – Isolated	c	Removable media		Diversified media format	N/A
	b	Manual		Dedicated data	
	a	No interoperation			

The capability model defines a set of attributes to achieve the certain level of interoperability to provide the basis for evaluating interoperability levels. It further refines the levels into sub-levels, identified as a, b, c, d. For example, 0a refers sublevel a in the level 0. 3 sub-levels are identified for level 0, 4 for level 1, and 3 for level 2, 3, and 4 respectively.

III. INTEROPERABILITY MEASUREMENT

A. AHP Analysis

To evaluate quantitatively, it can be transformed to a multi-criteria decision-making problem. That is, system interoperability is defined by multiple attributes from different layers and levels. We use Analytical Hierarchy Process (AHP) to evaluate the weight of each parameter. AHP is a widely used method for making decisions of complex problems with multiple criteria. It formalizes the decision-making algorithm, and allows for consideration of both qualitative and quantitative decision elements. Essentially, AHP involves interpreting the decision process as a series of one-on-one comparisons, and then synthesizing the results, in the process establishing a clear basis upon which the final decision was made. The general AHP procedure is as follows [6]:

1) Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it, and the criteria for

evaluating the alternatives.

2) Establish priorities among the elements of the hierarchy by making a series of judgments based on pairwise comparisons of the elements. For example, when comparing potential real-estate purchases, the investors might say they prefer location over price and price over timing.
3) Synthesize these judgments to yield a set of overall priorities for the hierarchy. This would combine the investors' judgments about location, price and timing for properties A, B, C, and D into overall priorities for each property.
4) Check the consistency of the judgments.
5) Come to a final decision based on the results of this process.

Following the AHP method, the capability model can be abstract into a hierarchical model for evaluation with multiple criteria, as shown in Fig. 4. The elements in Table 1 Capability Model are mapped to the hierarchical model as follows:

1) The layers, System Environment, Platform, Information Exchange, and Applications, are mapped to the four alternatives, E, P, I, A, respectively.
2) The levels of different layers (such as 0a, 0b, 4a, 4c) are mapped to the criteria of different alternatives.
3) The elements at each level of each layer are mapped to the indicators of each criteria.

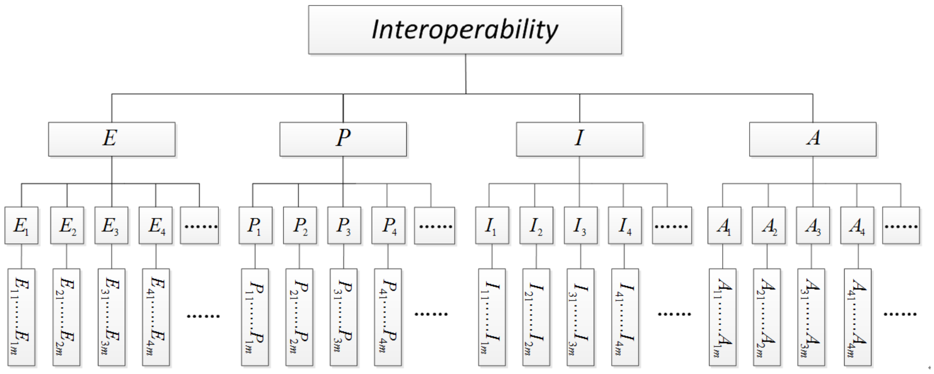

Fig. 4. The hierarchical model of interoperability evaluation problem. The model is divided into four levels including goal (Interoperability), alternatives for reaching goal (E for *System Environment*, P for *Platform*, I for *Information Exchange*, A for *Applications*), criteria for evaluating alternatives (E_i, P_i, I_i, and A_i), and finally the indicators for evaluating criteria (E_{ij}, P_{ij}, I_{ij}, and A_{ij}).

The next step, we use one-to-one comparison of parameters, and build pair-wise comparison matrix (judgment matrix). Taking P as an example, it contains 16 criteria from low to high, denoted as { p_1, p_2, p_3,…, p_{16} }. M_p is comparison matrix, as follows.

$$M_p = \begin{pmatrix} m_{1,1} & m_{1,2} & \cdots & m_{1,16} \\ m_{2,1} & m_{2,2} & \cdots & m_{2,16} \\ \cdots & \cdots & \cdots & \cdots \\ m_{16,1} & m_{16,2} & \cdots & m_{16,16} \end{pmatrix}$$

In this matrix, $m_{i,j}$ denotes the relative significance of any two criteria p_i and p_j, that is, $m_{i,j} = w_{p_i} / w_{p_j}$, where w_{p_i} and w_{p_i} are the weight of p_i and p_j, respectively.

Based on the pair-wise matrix, the relative weight of each parameter is defined as the eigenvector. Taking M_p as example, its eigenvector W is defined by $M_p W = \lambda_{\max} W$. $\lambda_{\max}$ is calculated as follows:

1) Normalize each column in the judgment matrix.

$$\overline{m}_{i,j} = \frac{m_{i,j}}{\sum_{i=1}^{16} m_{i,j}}, \ (i, j = 1,2,\cdots,16)$$

2) Sum up the values of each row in the judgment matrix.

$$\overline{W}_i = \sum_{i=1}^{16} \overline{m}_{i,j}, \ (i, j = 1,2,\cdots,16)$$

3) Calculate normalizing vector. The result of the normalizing vector $W = (W_1, W_2, \cdots, W_{16})^T$ is the eigenvector.

$$W_i = \frac{\overline{W}_i}{\sum_{i=1}^{16} W_i},$$

4) Compute the principle eigenvalue.

$$\lambda_{\max} = \sum_{i=1}^{16} \frac{(M_p W)_i}{n W_i}$$

Once the weight is decide for each criteria, the decision goal, interoperability, is calculated as a weighted sum of the criteria.

B. ANP Analysis

ANP can be considered as a more generalized AHP process for multi-criteria decision analysis [7]. Different to the hierarchical model, it uses a network structure to analyze the inter-dependences and relationship between any two elements. A general ANP procedure is as follows:

1) Define the control criteria.
2) Define a set of network clusters and their elements.
3) Identify the network clusters for each control criteria. Identify the influences between any two clusters and their elements and denote as dependent relationship in the model.
4) Perform pair-wise comparison within the network and across network clusters.

In this research, four network clusters are identified corresponding to the four layers of interoperation analysis.

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C_E is the cluster of elements in *System Environment*, C_p for *Platform*, C_I for *Information Exchange*, while C_A for *Application*.

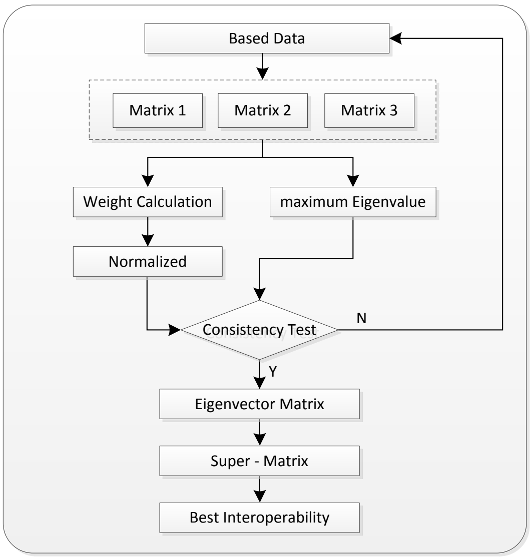

Fig. 5. The calculation process of ANP. Base data are collected from experts to identify the importance of each element in the decision system. Matrix are defined for each network and among the networks. The optimization plan of interoperability is determined by calculating the eigenvector matrix of the network clusters.

Fig. 5 shows the calculation process. Base data identify the relative importance of each network cluster and its components, which are the weight of the elements. The data are gathered following Delphi method [8] to collect evaluations from domain experts. The matrixes are built for each network clusters, and between the clusters. The eigenvalues are calculated for each matrix to decide the optimization plan for the system.

C. Case Study

Suppose that three plans are proposed for an information system, say S_1, S_2, and S_3. The system are expected to achieve 3c level interoperability. The four matrix for each layer capability is defined as follows.

$$B_E = \begin{pmatrix} \cdots & 0.335 & 0.554 & 0.134 \\ \cdots & 0.281 & 0.298 & 0.342 \\ \cdots & 0.384 & 0.148 & 0.212 \\ \cdots & 0 & 0 & 0.112 \\ \cdots & 0 & 0 & 0.200 \end{pmatrix}$$

$$B_P = \begin{pmatrix} \cdots & 0.532 & 0.325 & 0.126 \\ \cdots & 0.216 & 0.574 & 0.358 \\ \cdots & 0.143 & 0.101 & 0.167 \\ \cdots & 0.109 & 0 & 0.215 \\ \cdots & 0 & 0 & 0.134 \end{pmatrix}$$

$$B_I = \begin{pmatrix} \cdots & 0.339 & 0.441 & 0.211 \\ \cdots & 0.143 & 0.279 & 0.165 \\ \cdots & 0.228 & 0.280 & 0.232 \\ \cdots & 0.098 & 0 & 0.392 \\ \cdots & 0.192 & 0 & 0 \end{pmatrix}$$

$$B_A = \begin{pmatrix} \cdots & 0.592 & 0.126 & 0.311 & 0.114 & 0.273 & 0.335 \\ \cdots & 0.247 & 0.421 & 0.264 & 0.255 & 0.552 & 0.196 \\ \cdots & 0.161 & 0.371 & 0.115 & 0.386 & 0.175 & 0.278 \\ \cdots & 0 & 0.082 & 0.202 & 0.245 & 0 & 0.191 \\ \cdots & 0 & 0 & 0.108 & 0 & 0 & 0 \end{pmatrix}$$

The weight vector of sub-level properties are defined as shown in Table 2. The interoperation profile between different component of the three system development plan are defined as follows.

$$E^{(S_1,S_2,S_3)} = \begin{array}{c} \begin{array}{ccc} \quad S_1 \quad & \quad S_2 \quad & \quad S_3 \quad \end{array} \\ \left(\begin{array}{ccccc:ccccc:ccccc} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \end{array}\right) \end{array}$$

$$P^{(S_1,S_2,S_3)} = \begin{array}{c} \begin{array}{ccc} \quad S_1 \quad & \quad S_2 \quad & \quad S_3 \quad \end{array} \\ \left(\begin{array}{ccccc:ccccc:ccccc} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{array}\right) \end{array}$$

$$I^{(S_1,S_2,S_3)} = \begin{array}{c} \begin{array}{ccc} \quad S_1 \quad & \quad S_2 \quad & \quad S_3 \quad \end{array} \\ \left(\begin{array}{ccccc:ccccc:ccccc} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \end{array}\right) \end{array}$$

$$A^{(S_1,S_2,S_3)} = \begin{array}{c} \begin{array}{ccc} \quad S_1 \quad & \quad S_2 \quad & \quad S_3 \quad \end{array} \\ \left(\begin{array}{ccccc:ccccc:ccccc} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 \end{array}\right) \end{array}$$

TABLE II
THE VECTOR OF WEIGHT FOR THE CASE STUDY SYSTEM

	Weighting Vector	Consistency Checking
E	$[0.0555\ 0.0583\ 0.0730\ 0.0961\ 0.1204\ 0.1434\ 0.1985\ 0.2548]^T$	0.0138<0.1
P	$[0.0485\ 0.0504\ 0.0525\ 0.0546\ 0.0654\ 0.0883\ 0.1168\ 0.1344\ 0.1675\ 0.2216]^T$	0.0160<0.1
I	$[0.0735\ 0.0847\ 0.0977\ 0.1228\ 0.1589\ 0.2114\ 0.2509]^T$	0.0148<0.1
A	$[0.0395\ 0.0410\ 0.0425\ 0.0528\ 0.0611\ 0.0720\ 0.0832\ 0.1054\ 0.1219\ 0.1544\ 0.2262]^T$	0.0237<0.1

The base data are collected and normalized to evaluate system interoperability at different layers, and the pair-wise comparison matrixes are constructed for each property, as listed below.

- Pair-wise comparison matrix for S_1

$$\begin{array}{c} \\ E \\ P \\ I \\ A \end{array} \left(\begin{array}{cccc:c} E & P & I & A & V \\ \hdashline 1 & 0.9235 & 0.8303 & 0.7883 & 0.2195 \\ 1.0828 & 1 & 0.8991 & 0.8536 & 0.2377 \\ 1.2044 & 1.1123 & 1 & 0.9494 & 0.2644 \\ 1.2685 & 1.1716 & 1.0533 & 1 & 0.2785 \end{array}\right)$$

- Pair-wise comparison matrix for S_2

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$$\begin{array}{c} \\ E \\ P \\ I \\ A \end{array} \left(\begin{array}{cccc:c} E & P & I & A & V \\ \hdashline 1 & 0.7974 & 0.4701 & 0.4880 & 0.1555 \\ 1.2540 & 1 & 0.5896 & 0.6119 & 0.1950 \\ 2.1270 & 1.6962 & 1 & 1.0380 & 0.3308 \\ 2.0492 & 1.6341 & 0.9634 & 1 & 0.3187 \end{array} \right)$$

- Pair-wise comparison matrix for S_3

$$\begin{array}{c} \\ E \\ P \\ I \\ A \end{array} \left(\begin{array}{cccc:c} E & P & I & A & V \\ \hdashline 1 & 0.5212 & 0.5787 & 0.6069 & 0.1589 \\ 1.9186 & 1 & 1.1103 & 1.1644 & 0.3048 \\ 1.7280 & 0.9007 & 1 & 1.0488 & 0.2745 \\ 1.6477 & 0.8588 & 0.9535 & 1 & 0.2618 \end{array} \right)$$

Based on the data above, we can construct the super matrix and compute the limit priorities of the stochastic super-matrix. The results is as follow.

$$\begin{array}{c} \\ P \\ A \\ I \\ D \\ S_1 \\ S_2 \\ S_3 \end{array} \left(\begin{array}{cccc:ccc} P & A & I & D & S_1 & S_2 & S_3 \\ 0 & 0 & 0 & 0 & 0.1790 & 0.1790 & 0.1790 \\ 0 & 0 & 0 & 0 & 0.2438 & 0.2438 & 0.2438 \\ 0 & 0 & 0 & 0 & 0.2902 & 0.2902 & 0.2902 \\ 0 & 0 & 0 & 0 & 0.2871 & 0.2871 & 0.2871 \\ \hdashline 0.3500 & 0.3500 & 0.3500 & 0.3500 & 0 & 0 & 0 \\ 0.3415 & 0.3415 & 0.3415 & 0.3415 & 0 & 0 & 0 \\ 0.3086 & 0.3086 & 0.3086 & 0.3086 & 0 & 0 & 0 \end{array} \right)$$

IV. Summary and Conclusion

The paper proposes a framework for characterizing and evaluating interoperability of Internet-based information systems. The interoperation requirements are identified for the 4 layers of typical information systems architecture, including infrastructure, platform, information, and application. For each layer, the capabilities are ranked into different levels and sub-levels. Capability evaluation of the whole system is then transformed to a multi-criteria decision making problem. The paper introduces the process to calculate weight matrix and super-matrix following AHP and ANP methods. A proof-of-concept case study is presented.

There have been various frameworks proposed for interoperability analysis. However, the generalized framework is hard to be mapped directly to internet systems and to evaluate qualitative. This research, driven by the interoperation requirements of network-centric information systems, makes an early attempt to identify interoperation elements corresponding to system architecture. The layered architecture is a good reference to analyze what are the elements contribute to system interoperability, and how they influence each other. Based on the analysis framework, a systematic evaluation process can be built based on the theory of decision making. Future work include more refinement of the analysis framework with real industry experiments.

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