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Service Science

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Abstract This paper is a first exploration of the relationship between service science and Grid computing. Service science is the study of value co-creation interactions among entities, known as service systems. Within the emerging service science community, service is often defined as the application of competences (resources) for the benefit of another. Grid computing is the study of resource sharing among entities, known as virtual organizations, which solve complex business, societal, scientific, and engineering problems. Within the Grid computing community, service is sometimes defined as protocols plus behavior. Both Grid computing and service science are connecting academic, industry, government, and volunteer sector collaborators on a range of projects including eScience, healthcare, environmental sustainability, and more. This paper compares and contrasts the notions of resource, entity, service, interaction, and success criteria for the two areas of study. In conclusion, new areas for collaborative inquiry are proposed.

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1 Introduction

Service science [2, 3] and Grid computing [6] are both emerging areas of research. Since most of the readers of this journal are pioneers working to establish Grid computing, we first introduce service science. The notion of *service* will be formalized more in the coming sections, but initially the reader should consider service to be defined as *the application of competence* (*resources*) *for benefit of another*. Our notion of science can be defined as *the agreed upon methods and standards of rigor used by a community to develop a body of knowledge that accounts for observable classes of phenomenon in the world with conceptual frameworks*, *theories*, *models*, *and laws*, *that can be both empirically tested and applied to the benefit of society.*

1.1 Service Science

Service science can be thought of as a *mashup* or integration of many areas of study known as service management, service marketing, service operations, service engineering, service computing, service human resources management, service economics, management of service innovation, service supply chain

and contracting (eSourcing), and others. One can make four preliminary observations about these many disciplines. First, in one way or another they all deal with types of resources. For example, service human resources management deals with people, service computing deals with information and information technologies, and service supply chains and contracting (eSourcing) deal with interacting organizations. People, information, technologies, and organizations can all be viewed as different types of resources with their own disciplines to study the way they can be applied or configured to create value. Second, some of the disciplines more than others attempt to integrate and coordinate resources for specific purposes, for example, service management, service engineering, and management of service innovation. Third, measurement is important in most of the disciplines, though criteria about what is good measurement may vary between the disciplines, for example, service economics, service management, and service engineering.

Fourth, and perhaps most problematically, one notices the need to modify the name of each discipline with the word "service." Vargo and Lusch [18] provide a foundational logic to understand why the modifier is needed, but suffice it to say society is transitioning from a worldview that sees value in goods (physical things) to a worldview that sees value realized in service exchanges (the application of knowledge via types of relationships for mutual benefit). This is especially problematic because the term "service" evokes many misconceptions and stereotypes. For example, government statistics that show the rise in the service sector, may count jobs as manufacturing jobs when they are part of a manufacturing company until those same jobs are outsourced to a company that provides the service back to the manufacturing company. In many cases the same people are doing the same job, but in the national accounts the jobs are now tallied differently. As another telling example, in general, the average American today is more likely to associate the concept "service job" with someone who works in a fast food restaurant than someone who works as a research professor in a university—even when that person is the university professor.

Service science (which is still slowly emerging, and may take twenty more years to become established) is inherently multidisciplinary, with a long-term goal of becoming truly interdisciplinary. The interdisciplinary goal will be realized only as bridging theories are found to integrate separate disciplines into a new whole. A key driving force behind the origins of service science is the desire of industry to hire, in potentially vast numbers, a new type of professional. The new professional will have deep knowledge in some existing discipline, and also be skilled in the integrated science and art of service design and value realization, by combining technology, business model, and social–organizational innovations to improve business and societal systems [9]. Collins and Kusch [4] distinguish between contributory expertise (deep knowledge enabling problem solving and contributions to a body of knowledge of a highly specialized discipline or sub-discipline) and interactional expertise (knowledge of terms, concepts, and approaches that allows dialogue and understanding of problems and opportunities in a specialized discipline or sub-discipline). The emerging service science professional, with a certificate in Service Science, Management, and Engineering (SSME) in addition to their home discipline degree, is a graduate who is both deep and broad. A service scientist must have deep contributory expertise in their home discipline and a great breadth of interactional expertise across the broad range of disciplines mentioned earlier. A visual metaphor might be that of a "T-shaped" person, broad knowledge on top resting on deep knowledge below. Some envision an effective 21st Century labor force of adaptive innovators, whose background and leadership abilities allow them to create consensus across a range of academic discipline silos and organizational functional silos [5].

From an industry perspective, the first driving force behind the demand for service science (short for SSME) is the need for a new type of professional who can lead in making service innovation more systematic and therefore a better investment choice. Many governments also see the need for service innovation to achieve important societal goals such as accessibility and sustainability. However, the ultimate success of this endeavor will likely depend on whether or not breakthrough theories can be developed in the academic research community. For example, can a unified theory of service marketing, service operations, and service computing be developed? What would such a theory be like? Imagine, as businesses that engage in information technology outsourcing do,

that the customer resources (marketing) and the provider resources (operations) can become part of a unified pool (computing). Of course, a more general theory of entities interacting to achieve outcomes that co-create value is needed.

Spohrer, Vargo, Maglio, and Caswell [16] provide three definitions as an initial stake in the ground to be critiqued and improved (or completely replaced):

> *Service science* is the study of the application of the resources of one or more systems for the benefit of another system in economic exchange.
> *Normative service science* is the study of how one system can and should apply its resources for the mutual benefit of another system and of the system itself.
> *Service science, management, and engineering* is the application of normative service science.

The normative worldview is that of populations of many types of service systems interacting to co-create value. The types of resources available and the way value is judged differ greatly depending on the type of service systems under study. For example, service systems include businesses, government agencies, people, families, community groups, and open source communities, to name just a few. These types of service systems interact (normatively, and certainly not always) to co-create value ranging from monetary value to reputation value, and many other types of value. Service systems both evolve (emergent, path dependent changes) and are designed (conscious changes). However, service systems do not always succeed in co-creating value or as much value as possible (short-term and long-term) and thus the fundamental problems addressed by SSME arise. Designing (creatively imagining and realizing) sustainable worlds with short-term and long-term value co-creation potential is the SSME challenge. Or more practically, attending to and repairing value creation and capture shortfalls. And perhaps most fundamentally, and following March's [11] notion of exploitation and exploration, how to manage investment to balance short-term gains (exist) and long-term survival (persist) in a dynamic and uncertain environment made up of populations of entities interacting with unpredictable outcomes.

1.2 Grid Computing

Grid computing lays an important foundation for service science. Grid computing provides both technological mechanisms for resource sharing and technological mechanisms for novel business models. Business models structure the many ways entities can interact to create and capture value. For example, business models can be based on a variety of notions such as purchase, lease, advertising, subscriptions, pay-per-use, transaction fees, taxation, and donations. Lovelock and Gummesson [8] have proposed a framework for the study of service based on a leasing model for provisioning access to resources. To a Grid technologist, coordinated resource sharing is the key problem [6]: "The real and specific problem that underlies the Grid concept is coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations. The sharing that we are concerned with is not primarily file exchange but rather direct access to computers, software, data, and other resources, as is required by a range of collaborative problem solving and resource brokering strategies emerging in industry, science, and engineering." The fluid environment of global enterprises today, where the formation of virtual organizations is characterized by both agility and flexibility, requires underlying computing infrastructures that are adaptive and responsive to ever-changing demands. Economic pressures also require maximum return on capital investments through the movement of computational work to available capacity. SSME is aligned in scale and concerned with many of the same elements of Grid computing

The next five sections of this paper will compare and contrast the notions of resource, entity, service, interaction, and success criteria as developed in both the emerging service science community and the Grid computing community. Finally, in the concluding remarks section, recommendations for further collaborative study between these two communities are proposed.

2 Resource

What is a resource? How do the two communities formalize them?

To a service scientist, everything is a potential resource, just waiting to be used to realize value in some way. Vargo and Lusch [18] in their Service-Dominant Logic proposal, suggest that the most fundamental dichotomy related to resources is that of operant and operand resources. Operant resources use operand resources to create value (realize some benefit for others and a future version of the operant resource). For example, a person (operant resource) may use a broom (operand resource) to realize the value of a cleaner abode for those who live there. Given the importance of resources and the strong property laws of societies at this time, Spohrer, Vargo, Maglio, and Caswell [16] develop the notion that there are four types of resources in a formal service system governed by laws around rights and responsibilities: people (physical with rights), organizations (conceptual, that is socially constructed and not objectively physical, with rights), shared information (conceptual as property), and technology (physical as property). Within each of these categories operant and operand resource distinctions can be made. For example, if someone says the "software problem caused the experimental vehicle to crash" then the software is being judged by an observer to be the operant resource acting upon the experimental vehicle as the operant resource. In any service system, whether formal or informal, entities with behavior in accordance with the normative model are typically rewarded (value created) and those with behavior not in alignment with the normative model are typically punished (value destroyed), but not always. For examples, entrepreneurs or Prime Movers (Normann [12]) creating new value are examples where variations from the norm can occasionally be greatly rewarded. The rewards can be very great if the entrepreneur is judged by other service systems as solving a key outstanding problem of society at that time (e.g., information overload and Google).

To a Grid technologist, everything with behaviors that can be wrapped in a formal software protocol is a resource, to first approximation. For example, servers, storage systems, communication, systems, sensors, and robots are all examples of resources that may be found on a Grid [6]: "In particular, we see a need for highly flexible sharing relationships, ranging from client-server to peer-to-peer; for sophisticated and precise levels of control over how shared resources are used, including fine-grained and multi-stakeholder access control, delegation, and application of local and global policies; for sharing of varied resources, ranging from programs, files, and data to computers, sensors, and networks; and for diverse usage modes, ranging from single user to multi-user and from performance sensitive to cost-sensitive and hence embracing issues of quality of service, scheduling, co-allocation, and accounting."

From a Grid computing perspective, software technology can be used to expose the interaction and monitoring protocols that allow resources to be accessed and effectively applied in value creating activities, From a service science perspective, the role of management (inside a firm) and the role of markets and legal institutions (in an economy) can be used to expose the interaction and monitoring mechanisms that allow resources to be accessed and effectively applied in value creating activities. The parallels are clear, and as more of business and societies resources become accessible and monitorable on-line, the question of what is gained and what is lost in this formalization will need to be explored.

Building from a legacy in high performance computing, and supported by government initiatives such as National Science Foundation, Department of Energy, and National Aeronautics and Space Administration, there are a number of operational global Grids enabling 21st Century science, as well as developing the supporting computing infrastructure components for this new paradigm. National Science Foundation's cyber-infrastructure program and their TeraGrid are examples of these Grids (www.teragrid.org/).

Grid Computing is being exploited by academic and commercial organizations. The early success of SETI@Home encouraged other Grid applications such as the (protein) Folding@Home project, which investigates potential cures for Alzheimer's, AIDS and Parkinson's, and Butterfly.net, a Grid-based gaming network. The ClimatePrediction.net addresses global warming.

Discipline-based Grids are also operational, such as the Grid Physics Network (GriPhyN), which is focusing on developing petascale virtual data Grids to address problems requiring analysis of data at the petascale level and beyond. www.griphyn.org. European Organization for Nuclear Research (CERN)'s Compact Muon Solenoid project has a virtual organization of 144 institutions worldwide and 1,700 collaborating scientists (cms.cern.ch).

Marcus Kazmierczak in his 1997 Internet History points out that the Internet and the Web are different. *The Internet is the whole enchilada*, it is many types of service including e-mail, gopher, the web, newsgroups, ftp, IRC, and more. The World Wide Web is just one subset of the Internet. Negative consequences also have arisen from the rise of the internet, pervasively connected systems and devices, and adoption of standard protocols. Denial of service attacks and hacking incidents that exploit vulnerabilities in the software infrastructure were common in the 1990s. The overwhelming onslaught of e-mail spam, with sometimes accompanying identity theft is a side effect of standard e-mail protocols and globally connected systems. These problems speak to the need for continued work on foundational software and security infrastructures (Grid computing plus) as well as over-arching governance frameworks (service science and systems).

3 Entity

What is a service system? How does that notion relate to the notion of a virtual organization?

To a service scientist, the fundamental entity to be studied is a service system [16]. A formal service system is a legally recognized entity such as a person, corporation, government agency, or household (for tax and census purposes). Legal recognition is itself a potentially very complex value co-creation interaction between two services systems, one of which is known as a governing *authority* that provides rights to a responsible customer (citizen). Formal service systems can enter into a great number of formally sanctioned interactions with other service systems, designed to co-create value or remedy an unlawful act of value destruction. These interactions will be discussed in more detail in a later section.

For our purposes here, the important distinction is between formal service systems and informal service systems. Informal service systems may include the formation of a project team of people within an organization, or other loose collections of formal service systems that routinely interact to co-create value. Informal service systems have not sought any formal recognition by some governing authority service system. Typically, such recognition is sought for the purpose of resolving real or anticipated problems that arise from departures in the normal value co-creation interaction patterns between service systems. When we use the term service system, we mean formal service system unless otherwise specified. However, it should be noted that an enormous amount of value is created by informal service systems, and often formal value co-creation interactions would not be possible without antecedent informal service system interactions.

Service systems [13–16] are dynamic value co-creation configurations of resources (of the four logical types mentioned previously—people, organizations, shared information, and technology), where at least one resource is an operant resource, specifically a person with rights, and capable of interacting and judging outcomes. Service systems are connected to other service systems via value propositions. Value proposition help establish mutually agreed to expectations about realizable value co-creation potential [1].

For a service system to exist it must create and realize value propositions. This is the bread and butter or nuts and bolts of service systems existence—design, propose, agree, and realize value propositions with other service systems. However, for a service system to persist it must dynamically adapt its value propositions to adjust to the changing ecology of service systems. Value proposition must change over time because service systems and the relative populations of types of service systems change over time. The type of value proposition leads to four major views of service systems, as provider, customer, authority, or competitor. Providers interact with partners and employees as well as customers to co-create value. Providers must strategically design their value propositions with customers, partners, employees, and authorities, to persist in the face of competitors, entrepreneurs and criminals. Therefore, the design of effective value propositions requires in fact eight views on each service system: provider, customer, authority, competitor, partner, employee, entrepreneur, and criminal. For example, how many businesses have seen their customers turn into competitors, or employees into entrepreneurs? Of course, a very dangerous transition is authority to criminal, and many safeguards must be designed to prevent this.

To a Grid technologist, not every resource with the potential of being shared is pure technology, even

though most resources may someday have software protocol wrappers. For example, individual and institutions and the resources they control can be viewed as a special type of resource known as a virtual organization (VO). VOs have a say in the way sharing may occur [6]: "This sharing is, necessarily, highly controlled, with resource providers and consumers defining clearly and carefully just what is shared, who is allowed to share, and the conditions under which sharing occurs. A set of individuals and/or institutions defined by such sharing rules form what we call a VO. The following are examples of VOs: the application service providers, storage service providers, cycle providers, and consultants engaged by a car manufacturer to perform scenario evaluation during planning for a new factory; members of an industrial consortium bidding on a new aircraft; a crisis management team and the databases and simulation systems that they use to plan a response to an emergency situation; and members of a large, international, multiyear high energy physics collaboration. Each of these examples represents an approach to computing and problem solving based on collaboration in computation- and data-rich environments. As these examples show, VOs vary tremendously in their purpose, scope, size, duration, structure, community, and sociology. Nevertheless, careful study of underlying technology requirements leads us to identify a broad set of common concerns and requirements."

Are virtual organizations and service systems identical concepts? No, not at this stage and it is too early to tell what might be gained by making them identical. Nevertheless, the potential to unify these two concepts does exist. What is significant is that both the Grid computing community and the service science community understand the need for entities that have rights associated with resource access and usage. How the two communities choose to formalize these notions, as well as leave room for informal (open system) interactions remains to be seen.

Unifying virtual communities and social sector organizations requires the Grid to provide the ability for communities to share resources as they tackle common goals. Science today is increasingly collaborative and multidisciplinary, and it is not unusual for teams to span institutions, states, countries and continents. E-mail and the web provide basic mechanisms that allow such groups to work together. As Grid computing matures, more flexible resource sharing will become possible. As service science matures, more flexible value propositions to incentivize resource sharing will become possible.

4 Service

What is service?

To a service scientist, service is the application of competences (knowledge, resources) for the benefit of another [18]. There is a lot implicit in this simple statement that must be teased out and made explicit. First, one or more entities must ultimately perform the application of competences, and one or more entities must receive the benefit. Untold numbers of resources, distributed across space and time may be involved. Specifically, entities (service systems) are interacting, creating outcomes, and judging, directly or indirectly, the value co-created by those interactions. If service is a hair cut or even making a cell phone call, the analysis may be straightforward. However, if the service is life support for an abandoned baby or injured elderly person, the analysis may be far from straightforward. Furthermore, it is left implicit that value is co-created. In other words, all entities judge value is created. How can a baby judge value creation? In these situations, legally there is some other service system (some entity) that is authorized to represent and act on behalf of the baby. If value is not co-created, then a dispute may arise. Many other unusual cases must be understood by a service scientist, such as when the application of competences (dieting and exercising) is for the benefit of the future version of the service system. Businesses and governments routinely make investment for the benefit of future versions of themselves as well.

Von Mises (1998) [19], originally writing about human action and value judgements in the 1950s, suggested that all value is ultimately a human judgment about a change (or prevented change) in the world. Value creation depends on a change happening or being prevented from happening. A change can be a physical, mental, or social (shared mental). Furthermore, a single person may have multiple judgments about the same change. Multiple judgments arise because people may have short-term and long-term views, as well as may be in multiple roles in service systems (parent, employee, shareholder, citizen, etc.). Pareto efficient changes to the world are changes in

which one or more entity can have value creation improved, without decreasing any other entity. In the real world, it is almost always the case that any improvement of one entity will be perceived by some other entities negatively. Kaldor–Hicks' efficient changes to the world are changes in which the gains realized by one set of entities, can be used in part to offset loses realized by other entities negatively affected by the change, in such a way that everyone judges value co-creation has occurred. In sum, the definition of service may seem intuitive and straightforward to many, but in practice true service may be difficult to achieve.

To a Grid technologist, a service is an entity that provides a specific capability [6]: "Service. A service is a network-enabled entity that provides a specific capability, for example, the ability to move files, create processes, or verify access rights. A service is defined in terms of the protocol one uses to interact with it and the behavior expected in response to various protocol message exchanges (i.e., 'service = protocol + behavior.')... A service may or may not be persistent (i.e., always available), be able to detect and/or recover from certain errors; run with privileges, and/or have a distributed implementation for enhanced scalability. If variants are possible, then discovery mechanisms that allow a client to determine the properties of a particular instantiation of a service are important."

While a service may be more formally specifiable by a Grid technologist than a service scientist, both communities must research what happens when things go wrong. Recovery is a well researched area in service marketing as well as in areas of computer science, but because different types of resources are involved, a more general theory of recovery is needed to bridge the two fields. Designing safeguards into contracts is very relevant in business to business service contact negotiations, as well as to economists working in the area of transaction cost economics [18]. In sum, research into recovery from service failures is an important area for future research.

Quality of Service (QoS) is one example of a measurement mechanism in computing services. QoS is used to prioritize traffic on a network or ensure agreed-to levels of performance. Service Level Agreements are a more general category of measurements in the delivery of computing services.

5 Interaction

What is an interaction?

To a service scientist, interactions between service system entities are what lead to outcomes [16]. The normative, or desired outcome, is of course win–win value co-creation. When two or more service systems interact, the outcome will be judged by each (as well as possible others) to determine whether value was created or destroyed from their unique frames of reference. As in the well known prisoners' dilemma, four possible outcomes are logically possible: win–win value co-creation, lose–lose value co-destruction, and then the two possibilities of one judges value is created, while the other judges value is destroyed.

For service systems engaged in a provider–customer interaction, the assessment of value depends heavily on the frame of reference of the service system making the judgment. This frame of reference depends on many factors including historical experiences as well as on expectations set at the outset. In physical systems, quality is often an absolute measure of properties of the physical artifact. In service systems, quality and satisfaction depend heavily on customer expectations. Variability derives from customer expectations as well as provider performance. In most physical systems, standard quality requires eliminating variability. In most service systems, the seeds of improved value propositions often lie in understanding and capitalizing on customer variability.

Designing value propositions and realizing their potential in interactions with customers is what service systems do in order to exist. Anderson, Narus, and von Rossu [1] provide data on what makes for successful value propositions. The design of a successful value proposition requires knowledge of: (1) the providers' capabilities and needs, (2) the customers' capabilities and needs, and (3) the competitors' capabilities and needs. Put another way, a provider can fail in one of three ways (1) if the customer does not accept the provider's value proposition and hence the provider is not allowed to fulfill the customer's need, (2) if the customer decides to satisfy the need on their own with self-service, and (3) if the customer decides to satisfy the need by interacting with a competitor. A fourth consideration that should be added in a population of highly innovative service systems is knowledge of what authority (the legal system) will allow, since in an

innovative service system a new capability or a new need may require regulatory approval. Entrepreneurial endeavors (such as Napster) sometimes gamble on required regulatory changes that favor their innovation. These four knowledge requirements for the design of successful value propositions are also reflected in pricing of service offerings: (1) cost plus pricing is based on the provider's costs, (2) value based pricing is based on the benefit derived by the customer, (3) strategic pricing is based on expected impact on competitors position in the market, and (4) regulatory pricing is based on what authority will allow. Pricing is one area of active research in the service science community [7].

When two service systems interact, how likely is it that there exists a value proposition that, if realized, can co-create value for both of them? The answer is far more often than one might think. Ricardo, a political economist, investigated this question in the context of designing optimal import-export policy for Great Britain in the early 19th Century. What he found is considered paradoxical by many, and has come to be known as the law of comparative advantage or Ricardo's law of association [12]. Nations include many businesses that thrive on a variety of types of exchange, and so if in aggregate two nations have complementary competences (i.e., one does one thing better, and the other does another thing better, and both nations needs both competences), then clearly a basis for exchange is established, and each nation does a little more of what they do best, and little less of what they do less well. This is the case of complementary competences. However, what Ricardo was able to show was that under a wide range of circumstances, *one nation could have superior competencies in all areas, and there still could be an improvement for both parties through exchange.* Furthermore, since experience or learning curves exist in most activities, the longer one engaged in exchange the more benefit both parties could potentially achieve!

Even when value propositions with realizable potential exist, many times interactions between two service systems will not result in value co-creation outcomes. To better understand the possible outcomes, the interact-serve-propose-agree-realize (ISPAR) model of service system interaction has been proposed [16]. Figure 1 shows the ISPAR model of service systems interaction episodes. Interaction episodes describe the sequence of activities that might be pursued by two interacting service systems. In this normative–descriptive model, there are ten possible outcomes:

1. Outcome (R): Realization of the proposed and agreed to value proposition. For a service system with a good reputation in the population of service systems, this is the desired outcome. For example, if a person brings a document to a notary to be notarized, and the service interaction is successful, value is co-created and both service systems realize the benefit from the service interaction. The value realization outcome (R) corresponds to a win–win interaction.

2, 3. Outcomes (-P) and (-A): A proposal may not be successfully communicated or understood by the other service system (-P), and so the interaction may be aborted. Or a proposal may be communicated, but activities between the service systems may not lead to an agreement (-A), and so the service interaction may be aborted. For example, if the requestor does not have proper identification, then the notary will not agree to notarize the document. If the requestor has not brought a document, the notary may not understand the requestor's attempt to have some abstract object notarized.

4, 5, 6. Outcomes (-D), (-K), and (K): The value of a proposed service interaction may not be realized, and it is possible that no dispute (-D) arises. For example, two service systems may have been collaborating on a risky venture that failed for a reason that both service systems accept as outside of their control, and hence no value is co-created and no dispute arises. Nevertheless, both service systems may have learned a great deal from the attempt. However, often when co-created value is not realized by one or both service systems, a dispute ensues. Alternatively, the two service systems may have been successful in their value co-creation efforts, but another interested service system impacted by their efforts steps forward. This may be the result of an unintended consequence. For example, a home owner may be in the process of selling their property to an organization that runs a resettlement program for families fleeing war-ravaged homelands, and the neighbors file suit to stop the sale, fearing a drop

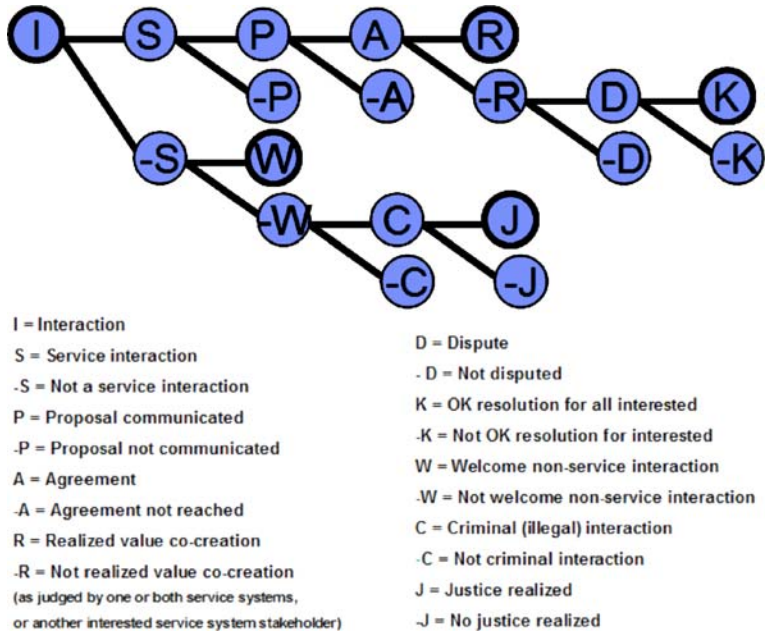

Fig. 1 The ISPAR model of service system interactions

in property values. When a dispute arises, the outcome can either be a successful resolution that is acceptable to all the stakeholders (K), or a resolution that is not acceptable to all the stakeholders (-K). Tapscott [17] has written extensively about the risks businesses take when the do not adequately understand their stakeholder webs as they seek to create value. In the case of a formal service interaction based on a formal contract between the two service systems, if a private resolution cannot be found, a law suit, and external governance mechanisms may be invoked to resolve the dispute.

7. Outcome (W). Many interactions between service systems are not service interactions (i.e., result in substantive value co-creation), but nevertheless the interaction may be welcomed (W) by both service systems. For example, exchanging pleasantries with a stranger that is passed on the street, or when businesses at a trade show exchange information. Such interactions may be voluntary and welcomed, but the amount of value co-created is typically very small, may be asymmetric, and the proposal and agreement exceptionally informal. However, (W) non-service interactions are not to be minimized. They often lay the foundation for future service interactions that may co-create great value. For example, when state visits between nations seek to establish better diplomatic relationships, the interactions may be welcomed, but are often a mere courtesy, and not a substantive service interaction with clear proposal and agreements expected. Nevertheless, again it should be emphasized that (W) non-service interaction are often foundational for future service interactions of a more substantive nature.

8, 9, 10. Outcomes (-C), (-J), and (J): When the interaction between service systems is not welcome by one or both service systems (e.g., confirming by comparing boarding cards that two passengers have been assigned the same seat on an overbooked flight), a judgment must be made as to the severity of the unwelcome (-W) non-service interaction. In the case of the double booked seats, this is likely not a criminal (-C) act. However, if one arrives home to discover a stranger in one's house, or sees an unauthorized stranger wandering about in an office, the -W may in fact be criminal (illegal) activity. If it is a criminal activity, a series of activities undertaken by several service systems interacting can result in justice (J) if the criminal is caught and punished, or in no justice (-J) if the intruder cannot be caught or escapes prosecution.

The ISPAR model enables us to see the world as populations of interacting service systems of different

types (people, businesses, government agencies, etc.). A great variety of entities can be unified by a single abstraction, and a great number of measurements can be developed. For example, the life span of a service system can be measured in terms of the number of interactions and types of outcomes with other service systems, rather than simply chronological time. The distribution of outcomes over time becomes an interesting signature in comparing service systems. Any pair of service systems has a history of interactions as well as a distribution of outcomes, and all the pairs of instances can be compared to look for patterns. Though the stability of a population of service systems might be measured as an increasing trend in the proportion of (R) outcomes to other types of outcomes, it may also indicate that a population of service systems is losing innovativeness. The quality of a service system might be measured as the trend in the ratio of (R) to all other outcomes combined.

Fully mapping the types of service systems that exist, the range of service interaction episodes during their life cycles, the way value co-creation is judged, and the way disputes are resolved are just some of the key problems in service science. Disputes and how effectively they are resolved is an important mechanism for learning and improvement of service systems. Disputes arise from hazards, and some are well studied by economists, such as bounded rationality and opportunism [20].

To a Grid technologist, interaction between entities requires specifying protocols [6]: "Protocol. A protocol is a set of rules that end points in a telecommunication system use when exchanging information… An important property of protocols is that they admit to multiple implementations: two end points need only implement the same protocol to be able to communicate. Standard protocols are thus fundamental to achieving interoperability in a distributed computing environment."

The design of governance mechanisms [20] in economic systems that exist in a political and legal context, and the design of Grid protocols for sharing resources of multiple interacting VOs is an area for further exploration. Both the design of software protocols running on a cyber-infrastructure and the design of contracts being executed by businesses operating in a legal system offer important test beds to understand the process of formalizing interaction patterns that what work better than others.

SETI@home is a Grid project that was launched in May, 1999 with the purpose of utilizing idle computer resources to analyze radio telescope data for signs of extraterrestrial life in the universe using thousands of computers from the general public. This is the first popular example of consumers voluntarily opting into a Grid, and has been followed by others with a humanitarian focus such as IBM's WorldCommunity Grid with a focus on cancer research and the human genome (www.worldcommunitygrid.org). Folding@home is a protein folding project initiated by Vijay Pande of Stanford University utilizing a large number of Windows, Linux, and Macintosh workstations, as well as Sony Playstation 3 systems. In each case, a set of guidelines and policies are specified detailing the computer resources that will be used (cpu cycles, disk space, network bandwidth), how the software agent works, and details about legal liability. For example, the user is able to specify whether or not the agent will run in the background, utilizing unused CPU cycles, or only in screensaver mode while the system is idle. For example: "Members will be able to control how much of their system resources are used by World Community Grid and will be given user preference options on a wide range of factors, including:

1. Whether the program runs as a screensaver or an application
2. When computation and communication can be done
3. Whether connections should be made automatically
4. Which proxies and firewall settings to use

The acceptable computing use policies of many companies do not permit participation in many of these Grid projects. This is an example where service science research, and the design of better value propositions, could help address overlapping constituencies and foster greater collaboration on a global basis.

6 Success Criteria

What constitutes success?

To a budding service scientist, success requires both relevance and rigor. More and more scientists and engineers from all disciplines find themselves embedded in a global knowledge-based economy that some economists refer to as a service economy. But what is service? What does it mean to the practical work they must undertake in their professional lives

and careers? To help scientist and engineers answer these questions, industry and government are increasingly calling on academics to make sure that the SSME-certified bit is set on their graduates, independent of their home discipline. This is a very practical first step that can be accomplished within a short period of time, and should provide graduates with access to basic vocabulary and concepts. For example, a worldview like Service-Dominant Logic that is grounded in interacting providers and customer (service systems in our vocabulary) seeking to co-create value has many direct applications for improving business and societal systems that a production-only view too often neglects [21].

What comes next is much more difficult. Kurt Lewin said "There is nothing as practical as a good theory." A rigorous theory of service systems, which includes answers to what they are as entities, how they interact, how they exist, how they persist, what outcomes they co-create, will certainly require integrating theories across many disciplines that have specialized on specific types of resources to the exclusion of others. This unification is no small undertaking, and the existing conceptual frameworks barely scratch the surface of what is needed. However, the preliminary conceptual frameworks do begin to point out the need and the opportunity for a breakthrough in integrative systems thinking around the service system concept.

Why will this effort succeed when so many previous attempts not unlike service science, from general systems theory to organization theory have not fulfilled their full promise in spite of laying many foundational insights? First and foremost is the demand for vast numbers of professionals like service scientists. Professional (who can be adaptive innovators with both a deep understanding of science and technological capabilities and change, as well as come equipped with a broader understanding of the way businesses actually work in practice through consensus building across functional silos to create successful value propositions and service offerings) are in high demand. Second, the capability to model and simulate complex business and societal systems (service systems) is improving at an incredible rate, again driven by real demand from businesses and government agencies. Third, Grid computing is providing practical platforms as well as exemplars of the coevolution of technological capabilities and new business models around the theme of formal resource sharing protocols.

To a Grid technologist, a shared language that enables the community to discuss problems and potential solutions, as well as interact with those in other fields is key [6]: "We hope that the vocabulary and structure introduced in this document will prove useful to the emerging Grid community, by improving understanding of our problem and providing a common language for describing solutions. We also hope that our analysis will help establish connections among Grid developers and proponents of related technologies."

The success of ambitious undertakings often hinges on how well practical success criteria can be established. Simple steps that allow progress to be identified and rewarded without losing sight of the end objective are especially valuable. Both service science and Grid computing have zeroed in on the notion of entities with associated resources interacting through exchange of service for service in a mutually beneficial manner. Rewarding those who can further refine a shared language for both communities, without over simplifying the important differences, is our recommendation for a mutual success criterion.

The Open Grid Forum (www.ogf.org/documents/GFD.107.pdf) has developed a Web Services Agreement Specification using an extensible XML format to standardize terminology and definitions, as well as protocols for service element interactions. This provides a well-defined and precise set of terms and a framework for interpreting and measuring results. "The specification consists of three parts which may be used in a composable manner: a schema for specifying an agreement, a schema for specifying an agreement template, and a set of port types and operations for managing agreement life-cycle, including creating, expiration, and monitoring of agreement states."

7 Concluding Remarks

Powerful dynamics are in play around world when it comes to applying resources effectively to solve problems and create value. For example, if the market value of a firm with publicly traded stock should ever dip below the cumulative separate value of the assets

(resources) that make up a firm, then the firm is in big trouble. Such a firm becomes a target for take over and liquidation of assets and severe restructuring. The fiduciary responsibility of the executives of such firms is to generate the largest possible returns on the resources of the firm for the shareholders. Some view the high failure rate of businesses as simply the unbundling and rebundling of resources into higher value creating configurations.

This paper has provided a first comparison of some of the foundational concepts that underlie two communities of researchers working to build practical systems as well as vocabulary and frameworks to understand some aspects of these powerful dynamics associated with resource utilization. The Grid computing community is developing software technologies for virtual organizations to share resources and collaboratively solve problems. The service science community is extracting and aligning disciplinary knowledge to create a new kind of professional who can be an adaptive innovator in a world of service systems interacting to co-create value. Both communities are reaching out across technology, discipline and organizational boundaries to collaborate with others and establish shared vocabulary and frameworks for making progress. While a deep integrative theory remains illusive and most likely at least twenty years away, nevertheless some opportunities for further collaboration have been identified:

1. Create a better understanding of the types of resources that exist, and methods to formally model their role in the design of effective value propositions.
2. Create a better understanding of the similarities and differences between entities that control and make use of resources, specifically service systems and virtual organizations.
3. Create a better understanding of governance mechanisms for entity interactions, specifically effective safeguards to ensure value realization as well as recovery from service failures.
4. Create a better understanding of the accelerators and barriers to establishing shared vocabulary for concepts across community boundaries.

Finally, we have just scratched the surface, and hope others will expand on this first exploration, and provide discussions that identify entities, interactions, and outcomes in related disciplines that study a type of resource used by service systems to co-create value with others.

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