A Science of Scaling: Service Hyper-Networks

Wai Kin Victor Chan, Cheng Hsu

Decision Sciences and Engineering Systems
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

Abstract

If Internet economies drive the growth of service science, then service hyper-networks may facilitate the understanding of the growth of Internet economies, such as the convergence of e-commerce and social networking. This new model analyzes the unprecedented promises of a digitally connected world for scaling: up (reaching the population), down (personalization), and transformational (new business designs). It reveals the principle of designing multiple simultaneous layers of connections of persons and organizations on the same basic networks to inflate value propositions (business spaces) and enable massive, simultaneous value cocreations across the life cycles of persons and organizations. This is a new topic in networks science and a new method for service scaling design – e.g., the identification of leaders/hubs ("value worm holes") to expand business models. We provide a mathematical analysis and an agent-based simulation study to show the effects of inter-relating a person's multiple roles in his/her life cycle, where each role sparks a particular network. These results confirm that multi-layered networking (e.g., simultaneous multiple social networks) decreases exponentially the degrees of separation between any two nodes in the community (the hyper-network); and thereby increases the possibility for value proposition and cocreation.

1. A Brief Case for a New Service Science

The Cambridge Papers 2008 by Ifm and IBM [5] consummated the recent industry-led call for a new science of service. Many new studies have responded to this challenge. From the perspective of this paper, we further focus our analysis on a particular defining concept of service that the field generally recognizes: the ***cocreation of value*** by the customer and the provider. In other words, ***we consider any economic activity that cocreates value to be service***, or, at the least, ***to have the potential to be a service***. To be certain, the field has recognized some other defining properties for service, such as perishable, one-of-a-kind, and co-production [2, 8, 14, 15, 21, 22, 23]. We submit that cocreation of value actually encompasses their quintessential meaning. With this focus, we refrain from concepts that intentionally contrast service from manufacturing of physical products, since we do not think this differentiation is necessary or even progressive. And indeed, we do not attempt to differentiate service from agriculture, mining, or any other genres of economic activities at all. If, for example, manufacturing is done in a manner of direct value cocreation (e.g., custom made products/mass customization), then the craftsman/factory is a service provider just the same as a doctor or a consultant is. New service may transform manufacturing and other traditional industries, too.

This value cocreation focus lends itself to a focus on service systems that enable the cocreation – or, the direct connections of individual customers, providers, and resources everywhere in the world. Here, we recognize a uniqueness of the new service science: the study of ***service scaling*** via digital connections [10, 11, 12], to improve productivity, quality, and growth in Knowledge Economy [4, 9, 20]. The focus on digital connections scaling, in turn, leads to the need for a new analytical model to analyze the service networks and the networked services: the ***service hyper-networks***. The work in [7] presents such a model, which helps describe the analytic properties of service scaling and hence promise to help design the latter. We substantiate this concept here, based on [7].

Social networking enterprises, such as Google, YouTube, and Second Life, have taught businesses great new lessons about business: the ease with which they ***scaled up*** to the whole user population (or the whole business space), ***down*** to each user's personal needs, and ***transformational*** to create new business designs (from P2P to B2C, B2B, Portal, ICP, and so on). This concept of scaling is recognized as a core to the new service science. Can e-commerce/e-business and other genres of new service duplicate the same scaling? Can all these activities connect? How can we design the connections? New networks scientific understanding of the ***community*** of all the Internet-based activities, as a whole, promises to help answer these questions. We employ the concept of hyper-networks [12] to bring the newness into the fore. It expands on some previous concepts of networks science (see, e.g., [24]).

The Internet community is a prime case of ***hyper-networks***. It consists of a ***basic network*** of user nodes (persons and organizations), characterized by the physical Internet itself. On top of this basic network (or the digital connections infrastructure), the users have created, either by design or by demand, a myriad of ***layered networks*** to perform economic, social and other functions pertaining to the tasks in their respective life cycles. It is arguable that these economic and social networks have opened up many new types of value propositions and led to many new business designs and new genres of service for knowledge-based economies [1, 16, 18]. The rapid growth since Internet's inception is truly amazing: Is the growth sustainable? Will it accelerate even more? How does it power service innovation? Can we design success on the Internet? One needs to understand the analytic nature of the Internet community as a whole, i.e., as a hyper-network, to be able to answer these and other similar questions.

Analytic results of hyper-networks can help one interpret, explain, and extrapolate what happened. The analysis includes how single networks (single layers) interact with each other, and inflate their values from these interactions. Previous results in the field are concerned mainly with single networks: how they grow horizontally (expand a single relation) and, to a lesser extent, vertically (adding more relations as separate layers) (see, e.g., [9, 17]). Study of the interrelation of layers and, indeed, even the formulation of multi-layered communities, such as the Internet, has been few and far in between. The concept of hyper-networks provides a formal model to characterize the analytic structure of networks with multiple layers. The notion of layers also support differing abstraction of networks in particular thought models. In comparison, the usual model of social networks comprises of only one layer. Chapter 3 of [12] presents a set of propositions and theorems relating hyper-networks to service scaling. We synthesize them in the following basic proposition that this paper studies:

Service Scaling Proposition: Growth of Internet-based economic activities comes from three main sources, each of which spawns new value propositions and cocreation. They are (1) the growth of single networks (digital connections of persons and organizations); (2) the addition of new single networks; and (3) the interrelation of layers of single networks along and across a person's and an organization's life cycle tasks. We further submit that the interrelation of networking layers represents the most powerful source of value proposition inflation. The points of interrelation may be metaphorically referred to as the "***value worm holes***" (in the spirit of the "worm hole" concept of astrophysics). A value worm hole is multi-dimensional and multi-layered.

In the Internet community, we recognize value worm holes in Google and many other sites where social networking and e-commerce integrate (e.g., embedded B2C); which help explain their stellar growth. In general, the study of hyper-networks promises to provide insights into the design for service scaling, such as the identification and creation of the "value worm holes" to expand value propositions and facilitate value cocreation. Furthermore, the concept of hyper-networks expressly recognizes the fact that each person may become both providers and customers of certain value, just as organizations always are. The reason is simple: each person always possesses certain information and resources valuable to others in some context. The secret is, therefore, how to materialize these contexts (value propositions) and then connect them for value cocreation. We submit that such connections spell innovation of service. Clearly, interrelation of network layers connects these contexts and maximizes them for all to benefit. The result is the concept of hyper-networks, where each node can be a versatile partner in all kinds of value cocreation for all kinds of value propositions when the needs of all nodes are connected along their life cycles.

Section 2 further elaborates and formulates the conceptual model of hyper-networks, while Section 3 presents their mathematical models and derives their basic analytic properties based on probabilistic laws. Section 4 shows a preliminary study of the behaviors of hyper-networks under certain settings, using agent-based simulation. Agents are employed to implement the behavioral models associated with each mode. The simulation results serve as a baseline measure for interrelation of multiple layers based on roles of the behavioral models. The last section, Section 5, remarks on the implications of the study and their extensions in the future, and concludes the paper.

2. Service Scaling Design: The Conceptual Model of Hyper-Networks

Define H(B, N, E, M, R), where

H: a multi-dimensional hyper-network defined by parameters B, N, E, M, and P.

B: the basic network of H, defined by N and E and implemented by digital infrastructure.

N: the set of nodes of the basic network (size n)

E: the set of edges defined by available digital connections among the nodes of the basic network (E is of size n(n-1)/2 in an unrestricted network where any node can gain access to any other nodes).

M: the set of a priori defined roles available to N (i.e., each node has up to m defined roles), where each role defines a particular layer of networking out of N and E.

R: the (n x m) behavior matrix where each element is a model governing how the node performs each role. The simplest form for a behavioral model of an element in the matrix is a (n-1) vector of probabilities defining the chance of each node connecting to every other node for a given defined role.

The basic network is the physical foundation of hyper-networking. It does not have to be a layer of networks in the sense of users' connections (e.g., social networking); however, it could if the community happens to be constructed this way, as in a campus network. For our purpose, the above model recognizes it in order to highlight the nature of digital connections for hyper-networks – i.e., enabled by a physical foundation which itself is subject to design. Otherwise, it could be indistinguishable from the other layers and be removed from the model. In fact, our analysis (Section 3) and simulation (Section 4) do just this: they assume a pervasive basic network in the community and accordingly treat it as a constant outside of the scope of the study.

Each node is a person or an organization, and each edge is a digital connection. When all roles are isolated, then H is a mere collection of r single networks. However, when interrelated nodes and edges are present, then layers of networks are connected and the interrelating nodes become value worm holes for making value propositions and value cocreation across layers. For example, the social networking site Second Life is a "value worm hole" connecting persons whose lives may otherwise never get crossed paths. We review the basic promises of the above conceptual model below, to establish that it supports service scaling design.

A good measure for the power of interrelating network layers is the increase of connection – which opens up channels for value cocreation. Connection, in turn, may be measured by "degrees of separation", or the "small world" phenomenon [3, 25] of the networks science. The Service Scaling Proposition of Section 1 requires that, first, hyper-networks with multiple roles for persons and organizations allow significantly smaller degrees of separation than single networks; and second, connections lead to possibilities of value proposition and cocreation. At present, we take the second premise as it is - a given. Yet, the first promise may be justified by mathematical analysis and simulation – the task we undertake in the next sections. Before we indulge ourselves with the formal studies, we review the conceptual foundations of the above model.

Hyper-networks can evolve along any and every dimensions, by expanding R and P, as well as B. They are multiple (social and economic) networks convoluted (layered, with interrelation) into one (e.g., integration of B2C, B2B, B2E, P2P, etc.). From the perspective of service science, ***each hyper-network is a multi-dimensional user community for massive (possibly concurrent) value cocreation***. Each dimension corresponds to a networking layer, and a layer characterizes a particular type of ***role*** of the basic network governed by a particular behavioral regime for the nodes. In other words, a hyper-network is a basic network that plays a myriad set of simultaneous roles, each of which gives rise to a particular social or economic network. Each role defines a layer and a dimension of the holistic community, or the hyper-network. In a usual network, each node subscribes to just one behavioral model – which defines its sole role, such as dating, supply chain, and games. This characterization lends itself naturally to multi-agent implementation when we study how it works. In this way, a type of agent represents a particular role for a node when it subscribes to the particular behavioral model. A node, then, is operational when it completes with a set of multi-typed agents to perform its various roles.

Hyper-networks are both descriptive and prescriptive. That is, hyper-networks are subject to design: they can be proactively developed, from first digital connections and then promotion of value worm holes to facilitate massive simultaneous value cocreation among persons and organizations. The interrelation of layer networks amounts to multiple-role playing for nodes in the basic network, where each node is associated with an open number of behavioral models and hence types of role, for various value cocreation in various business spaces enabled by the same basic network. This openness affords the nodes a multitude, multiplex, and indeed multiplication of possibilities beyond the usual sense of scalability of networks. The word inflation might actually better describe this expansion. As such, the interrelation of layer networks promises to be a source of innovation and the opening of new spaces, which awaits exploitation. When hyper-networking is amenable to design, so does ***service scaling*** by virtue of ***designing*** hyper-networks: service scaling on hyper-networks. It follows that we study the analytic properties of hyper-networks to gain design knowledge for service scaling. We now explain this point further: why hyper-networks may help define new genres of service in Knowledge Economy, and why it may be central to a new service science (as discussed in, e.g., [5, 12]).

To do this, we turn to the foundation of the new service, which features hyper-networks: value cocreation. In this sense, service scaling is concerned with promoting value cocreation and the enhancement of service quality and productivity through new and better value propositions [10, 12]. This recognition leads to the Digital Connections Scaling (DCS) model for service science [10, 11, 12].

The DCS model theorizes that digitization makes service resources (people, organization, information, and technology) everywhere in the world connectible, and digital connections can (be designed to) scale up, down, and transformational, to spawn value cocreation for persons, organizations and society. The notions of customer and provider are in fact roles that persons and organizations play in the cocreation. These basic roles may interchange and evolve along the life cycles of the persons and organizations concerned, for the tasks of the value propositions involved at each stage of the life cycles. The scaling of value cocreation is, therefore, a function of the scaling of digital connections among persons, organizations, and society. Such digital connections are comparable to networking except that the networks involved can have numerous purposes and each node (person or organization) in the network can have numerous roles to play towards these purposes, simultaneously. In other words, the communities of value cocreation are really hyper-networks. Their role-based evolution is the layer-based evolution of the underlying hyper-networks.

We should point out that connection is a basic concept in many studies, ranging from organization [6] and sociology [24] all the way to biology [13]. Although researchers may take it for granted that the connections often employ digital means such as the Internet, many previous results tend to neglect the unique conceptual implications of digital connections. In contrast, the DCS model argues that digital connections are not just one type of connections; rather, they constitute a new world of connection in which service (value cocreation) dominates. In one word, digital connections scale: they can scale up to the population, scale down to personalization, and scale to transform. This again corroborates that a digitally connected world is a multi-dimensional community of many co-existing social and economic networks convoluted recursively into one: the community of hyper-networks. Just as the DCS concept is broad, so does that of hyper-networks. While social engineering borders impossibility for a community of non-digital connections, digitally connected communities are amenable for scaling design pursuing similar goals of value: numerous simultaneous networks can not only evolve into being by themselves, but they also can be facilitated from the basic networks which physically exists, and can operate to support many concurrent roles at any given time.

Since digital connections scaling naturally results in hyper-networks (e.g., the Internet), designing DCS to promote value cocreation and new value propositions is designing hyper-networks. Thus, if digital connections scaling makes any sense at all for the new service genres in the age of knowledge-based economies, which we think it does, then studying hyper-networks is inevitably valuable. As a first study, this paper explores the basic analytic properties of hyper-networks, to provide a basis for studies corroborating the concepts with the empirical evidence on the Internet. The results are presented in the next two sections.

3. Mathematical Models of Hyper-Networks

In this section, we derive the mathematical models for hyper-networks with multiple layers and dimensions. We assume that there are n individuals (or, nodes), $p_1, p_2, \ldots, p_n$, in the network. The network is called an m-role hyper-network if every member of it plays up to m roles in the network simultaneously. Each role substantiates a logical layer of networking, which may not connect to other layers by itself – i.e., each role is naturally distinct from other roles in the hyper-network.

To establish a logical edge for a role-based network, we employ the simple definition of probability prescribing the chance that a node may connect to another, in the tradition of networks science. That is, each role of an individual is characterized by a popularity factor, g_{li}. Individual p_i is acquainted directly with individual p_j under role l with probability $g_{li}g_{lj}$.

As discussed in Section 2, the power of multiple roles can be measured by the concept of degrees of separation. Our objective here is to examine how the degrees of separation changes due to the effect of multiple roles. We quantify the degrees of separation between two individuals by using the length of the shortest path between these two individuals. Specifically, if p_i is directly connected to p_j (i.e., known to each other) under anyone of the m roles that they play, the shortest path length between p_i and p_j is one. In general, if p_i is connected to p_j through $x-1$ members, the shortest path length between p_i and p_j is x. Let $X_{ij}^{(m)}$ be the shortest path length between individuals p_i and p_j in an m-role network, $i, j = 1, \ldots, n$.

In an m-role hyper-network, the connection between p_i and p_j can appear in anyone of the m roles. The probability that there is no direct connection between them is $\prod_{l_1 \in \mathbb{M}} (1 - g_{l_1 i} g_{l_1 j})$. Hence, the probability that there is at least one direct connection (of length one) between them is,

$$\Pr\left[X_{ij}^{(m)} = 1\right] = 1 - \prod_{l_1 \in \mathbb{M}} (1 - g_{l_1 i} g_{l_1 j}).$$

For a shortest path of length x, p_i and p_j are connected through $x-1$ intermediate members (i.e., $p_{k_1}, p_{k_2}, \ldots, p_{k_{x-1}}, \forall k_l \neq i, j$) under any combination of the m roles. The probability of that is:

$$\Pr\left[X_{ij}^{(m)} = x\right] = \prod_{q=0}^{x-2} \prod_{l_1,\ldots,l_{q+1} \in \mathbb{M}^{q+1}} \prod_{k_1,\ldots,k_q \neq i,j} (1 - g_{l_1 i} g_{l_1 k_1} g_{l_2 k_1} g_{l_2 k_2} \cdots g_{l_q k_{q-1}} g_{l_q k_q} g_{l_{q+1} k_q} g_{l_{q+1} j}) \left[1 - \prod_{l_1,\ldots,l_x \in \mathbb{M}^x} \prod_{k_1,\ldots,k_{x-1} \neq i,j} (1 - g_{l_1 i} g_{l_1 k_1} \cdots g_{l_{x-1} k_{x-2}} g_{l_{x-1} k_{x-1}} g_{l_x k_{x-1}} g_{l_x j})\right].$$

We also define the shortest path length between p_i and p_j as n if there is no connection between them under any role. The probability of that is:

$$\Pr\left[X_{ij}^{(m)} = n\right] = \prod_{q=0}^{n-2} \prod_{l_1,\ldots,l_{q+1} \in \mathbb{M}^{q+1}} \prod_{k_1,\ldots,k_q \neq i,j} (1 - g_{l_1 i} g_{l_1 k_1} g_{l_2 k_1} g_{l_2 k_2} \cdots g_{l_q k_{q-1}} g_{l_q k_q} g_{l_{q+1} k_q} g_{l_{q+1} j}).$$

For ease of exposition, define quantity $Q^{(m)}(x)$ as:

$$Q^{(m)}(x) = \prod_{q=0}^{x-1} \prod_{l_1,\ldots,l_{q+1} \in \mathbb{M}^{q+1}} \prod_{k_1,\ldots,k_q \neq i,j} (1 - g_{l_1 i} g_{l_1 k_1} g_{l_2 k_1} g_{l_2 k_2} \cdots g_{l_q k_{q-1}} g_{l_q k_q} g_{l_{q+1} k_q} g_{l_{q+1} j}).$$

where $Q^{(m)}(0) = 1$ and $Q^{(m)}(1) = \prod_{l_1 \in \mathbb{M}} (1 - g_{l_1 i} g_{l_1 j})$. As a result, we have:

$$\Pr\left[X_{ij}^{(1)} = x\right] = Q^{(m)}(x-1) - Q^{(m)}(x).$$

In summary, the distribution of $X_{ij}^{(m)}$ is given by,

$$X_{ij}^{(m)} = \begin{cases} x & \text{w.p. } Q^{(m)}(x-1) - Q^{(m)}(x), \qquad x = 1, 2, \ldots, n-1 \\ n & \text{w.p. } Q^{(m)}(n-1) \end{cases}.$$

We now compare the effect of multiple roles to the shortest path length in the following. It can be seen that the expected shortest path length decreases in the number of roles. All the proofs are omitted due to space limitation.

Theorem 1: The expected shortest path length decreases as the number of roles in the network increases, i.e.,:

$$E[X_{ij}^{(1)}] > E[X_{ij}^{(2)}] > \cdots E[X_{ij}^{(m)}].$$

The maximum and minimum effects (reduction in shortest path length) of multiple roles can be estimated by developing upper and lower bounds on $E[X_{ij}^{(m)}]$, respectively.

Theorem 2: The lower and upper bounds of $E[X_{ij}^{(m)}]$ are:

$$E[X_{ij}^{(1)}]\frac{Q^{(m)}(n-1)}{Q^{(1)}(n-1)} < E[X_{ij}^{(m)}] < E[X_{ij}^{(1)}]\frac{Q^{(m)}(1)}{Q^{(1)}(1)}.$$

When $g_i = g, \forall i$, these bounds can be further simplified.

Corollary 2: When $g_i = g, \forall i$, the lower and upper bounds of $E[X_{ij}^{(m)}]$ are:

$$E[X_{ij}^{(1)}](1-g^2)^{(2m)^{n-2}} < E[X_{ij}^{(m)}] < E[X_{ij}^{(1)}](1-g^2)^{m-1}.$$

Of particular interest is the upper bound of $E[X_{ij}^{(m)}]$, which specifies that the percentage of reduction in the shortest path length between two arbitrary individuals increases exponentially in the number of roles, i.e., $E[X_{ij}^{(m)}]/E[X_{ij}^{(1)}] < (1-g^2)^{m-1}$. For example, if $g = 0.5$, the shortest path length reduces to about 50% when the number of roles increases to three. In practice, this reduction can be bigger since this 50% is only the upper bound. Figure 1.a depicts this amount of reduction in the increase of the number of roles. It clearly shows that the degree of separation is reduced in reversed proportion exponentially to the expansion of roles in the hyper-network. This is a basic premise of the Service Scaling Proposition of Section 1. With this promise, design of hyper-networks can lead to design of service scaling.

4. AGENT-BASED SIMULATION OF HYPER-NETWORKS

In this section, we develop an agent-based simulation to exhibit the effect of multiple roles on the average shortest path length in a multiple-role social network. This work corroborates and generalizes the analytic results in Section 3 towards supporting the Service Scaling Proposition. The underlying assumptions and network properties of the simulation model are also discussed.

As in Section 3, we assume that there are n individuals (nodes), $p_1, p_2, \ldots, p_n$, in the basic network. Each individual plays m roles in the hyper-network. Each role of an individual is characterized by a popularity factor, g_{li}. Individual p_i is acquainted with individual p_j under role l with probability $g_{li}g_{lj}$. At the beginning of the simulation, these popularity factors (g_{li}'s) are generated them according to a uniform distribution in the interval of $(0, G)$, where G is a parameter to be varied in the experiment. Hence, each experiment can be considered as a realization of a social network with n individuals who bear different characteristics and personalities.

The objective of the simulation is to examine the effect of multiple roles on the degrees of separation. Unlike Section 2 where the shortest path between two arbitrary individuals is considered, in this simulation study we focus on the average shortest path length in the entire network. The shortest path length between individuals p_i and p_j is calculated as in Section 2. The average path length in the network is computed by taking the average of the path lengths among all individuals.

We re-use the notation in Section 3. Since there are totally $n(n-1)/2$ pairs of individuals (i.e., $n(n-1)/2$ shortest paths), the average shortest path length, $\overline{X}^{(m)}$, in an m-role network is calculated as,

$$\overline{X}^{(m)} = 2\frac{\sum_{\forall(i,j)} X_{ij}^{(m)}}{n(n-1)} \tag{1}$$

Note that if p_i does not connect to p_j under any role, the shortest path length is assumed to be n as discussed in Section 2. The steps of a simulation run are listed in the following:

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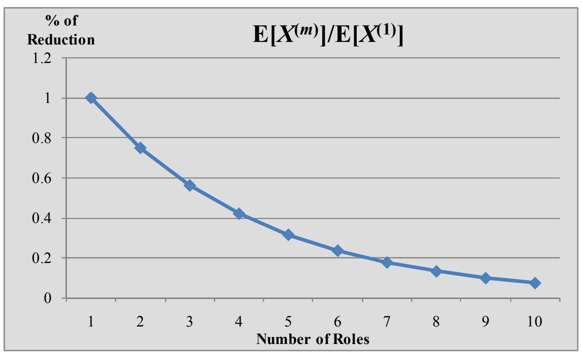
1. Setup n computer agents, $p_1, p_2, \ldots, p_n$.
2. Generate m popularity factor vectors (each of size n), where each element in a vector is distributed according to $U(0, G)$, i.e., $\{\{g_{l1}, g_{l2}, , \ldots, g_{1n}\}, l = 1, \ldots, m\}$, where $g_{li} \sim U(0, G)$.
3. For each pair of $\{(i, j); i, j = 1, \ldots, n\}$,
4. generate m independent uniform random variates $U_l \sim U(0, 1), l = 1, \ldots, m$ and

5. if there is at least one U_l such that $U_l < g_{li}g_{lj}$, then person i is directly connected to person j, otherwise, they are not directly connected.
6. For every two persons, persons i and j, $i, j = 1, \ldots, n$, calculate the shortest path length between them.
7. Compute the average shortest path length using Eq.(1).

We simulate a hyper-network evolved from a basic network of 100 nodes (interpreted as individuals, following the tradition of social networking). The number of roles changes from one to ten. For each role $l, l = 1, \ldots, 10$, the parameter, G, of the popularity factor is varied from 0.1 to 1 with an increment of 0.1. This results in 100 scenarios (i.e., ten values of roles times ten parameter values). For each scenario, 20 replications are performed and the average is taken. Figure 1.b shows the effects of multiple roles on the average path length. For example, the uppermost (blue) curve in the figure shows that the average path length decreases dramatically as the number of roles increases even under a relatively small popularity factor parameter of 0.1. Similar behavior can be observed under other parameter values of the popularity factor, as illustrated in the other nine curves in the figure.



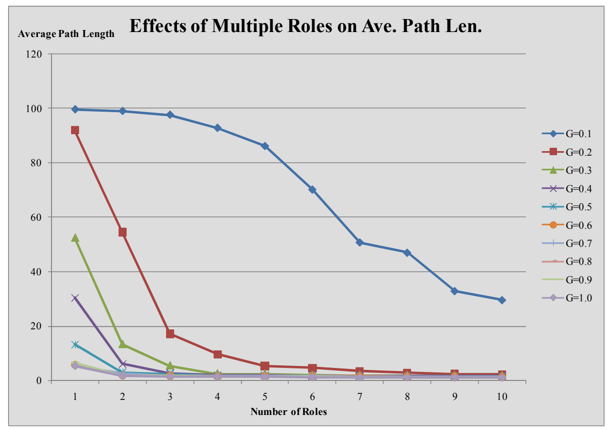


Figure 1. (a) Reduction in the Shortest Path Length (b) Effects of Multiple Roles on the Average Path Length

The above simulation is of a relatively small scale; however, it does exhibit unequivocally and consistently the same properties as predicted in the mathematical analysis in Section 3, especially Figure 1.a. These initial simulations corroborates with the premises of the Service Scaling Proposition in Section 1.

5. Remarks and Conclusion

The above sections have explored the basic analytic properties of hyper-networks for digital connections scaling in knowledge-based economies. Internet is a quintessential hyper-network. These properties promise to shed light on how innovative business designs may interrelate layers of networks, perhaps across a person's and an organization's life cycles, and thereby open up new types of value propositions, enhance value cocreation, and innovate service.

A proposition of service scaling (Section 1) leads to the formulation of the hyper-networks model (Section 2) to reveal the possibilities of reducing the degrees of separation for a community due to the recognition of multiple roles afforded to nodes (persons and organizations), and hence he possibilities of designing value worm holes which connect multiple layers. Less separation implies more density (opportunity) of value propositions and cocreation.

Probabilistic derivation shows that this is indeed the theoretic propensity promised by interrelating network layers (Section 3). Basic theorems developed in the section lay in critical foundations for further analysis of hyper-networks, for especially the design for service scaling. We then employ agent-based simulation to elaborate these results under some basic settings (Section 4). In the simulation, each agent type represents a particular behavioral model of roles for notes in a hyper-network, the value cocreation community simulated. The study extends some of the previous results of social networking into hyper-networks. It shows, for instance, the increase of roles does inflate the direct connection rate of nodes in the community, and hence corroborates the opening of avenues for unprecedented value propositions by virtue of digital connections scaling.

These results confirm the Service Scaling Proposition. Further studies will progress along two lines: more extensive simulation to reveal design principles, such as the identification of interrelating nodes and their behavioral models; and empirical studies to corroborate the analytic predictions. Clearly, as stated in Section 1, only the empirical corroboration can finally settle the studies of service scaling on hyper-networks.

Ultimately, we expect this line of studies leads to new addition to service science, furthering our understanding of what is the intellectual nature of new service in Knowledge Economy, how does it grow and improve quality and productivity of the society. Unlike the materialism of Industrial Revolution of the recent centuries, service promotes value, not material, and hence reflects a deepening of a sustainable Knowledge Economy for the world.

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