Technology Innovation Management Review

May 2013

Technology Evolution

Welcome to the May 2013 issue of the *Technology Innovation Management Review*. The editorial theme of this issue is Technology Evolution. We invite your comments on the articles in this issue as well as suggestions for future article topics and issue themes.

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Overview

The *Technology Innovation Management Review* (TIM Review) provides insights about the issues and emerging trends relevant to launching and growing technology businesses. The TIM Review focuses on the theories, strategies, and tools that help small and large technology companies succeed.

Our readers are looking for practical ideas they can apply within their own organizations. The TIM Review brings together diverse viewpoints – from academics, entrepreneurs, companies of all sizes, the public sector, the community sector, and others – to bridge the gap between theory and practice. In particular, we focus on the topics of technology and global entrepreneurship in small and large companies.

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Editorial: Technology Evolution

Chris McPhee, Editor-in-Chief

Michael Weiss, Guest Editor

From the Editor-in-Chief

Welcome to the May 2013 issue of the *Technology Innovation Management Review*. This month's editorial theme is Technology Evolution, and I am pleased to introduce our guest editor, **Michael Weiss**, who is a faculty member of the Technology Innovation Management (TIM) program (carleton.ca/tim), and who holds a faculty appointment in the Department of Systems and Computer Engineering at Carleton University in Ottawa, Canada.

June's issue will not have an editorial theme, but will include articles relating to our overall scope. Over the summer, we will be covering the theme of Cybersecurity. If you have expertise in cybersecurity and wish to contribute an article, please contact us.

Also, you may recall that several articles in our April issue on Local Open Innovation (timreview.ca/issue/2013/march) focused on the Seeking Solutions approach to solving challenging business problems, which arose from a series of Quebec Seeks Solutions events. The 3rd Quebec Seeks Solutions Conference will be held in Quebec, Canada on 5-6 November 2013, and the conference theme is: "Methods and Policies Creating a Local Ecosystem for Technology Transfer, Collaboration, and Local Innovation". The TIM Review is selecting submissions for the pre-event, and the best papers will be published in a future issue of the TIM Review. Abstracts are due June 28, 2013. Please consider submitting a paper to this conference and sharing this call for papers with your contacts: tinyurl.com/nqwdzd3

We hope you enjoy this issue of the TIM Review and will share your comments online. Please contact us (timreview.ca/contact) with article topics and submissions, suggestions for future themes, and any other feedback.

Chris McPhee
Editor-in-Chief

From the Guest Editor

Technology evolution is one of the least understood areas of innovation management. It is hard to predict the path a new technology will take, and yet the fortunes of companies and whole industries depend on how well changes in technology are managed. This issue contains three articles on technology evolution, one article on the evolution of business ecosystems, and a summary of April's TIM Lecture. All of the articles in this issue have been contributed by the faculty and graduate students of the Technology Innovation Management (TIM; carleton.ca/tim) program at Carleton University in Ottawa, Canada.

The first two articles in this issue make contributions to core issues in technology evolution; they create models based on insights from evolutionary biology for understanding the evolution of wireless standards and the evolution of mashups. The third article deals with how web-application developers can deal with the evolution of requirements and component technologies. The fourth article complements the discussion of technology with a discussion of the evolution of the business ecosystems in which technology companies participate.

Arthur Low, CEO of Crack Semiconductor, applies a framework of technology evolution based on the theory of punctuated equilibrium to the comparison of two wireless sensor network (WSN) standards for industrial instrumentation and control. This framework reconciles two contrasting perspectives on technological change: the gradual evolution of technology and its rapid and discontinuous commercialization.

Solange Sari, Nadia Noori, and I explain the evolution of mashups (applications created by end-users through "mixing and matching" data and services on the web) through the lens of speciation. We make visible how mashups can be “derived” from one another. This approach offers insights into future trends, can suggest templates to users upon which new mashups may be built, and can help identify opportunities for new types of tools.

Editorial: Technology Evolution

Chris McPhee and Michael Weiss

Antonio Misaka, recent graduate of Carleton University's Technology Innovation Management program, describes an approach for speeding up the development of web applications in the same domain using a configurable platform. The article deals with evolution of a different kind, namely, how requirements from business owners and technologies of the underlying components evolve with each new application. Instead of the traditional "clone-and-own" approach, Misaka suggests that companies create a configurable platform that addresses the common needs of the applications.

Derek Smith, founder and principal of Magneto Innovention Management, reviews the literature on risks related to the entry and participation in business ecosystems, and makes recommendations for entrepreneurs on how to manage those risks. He identifies three types of risks: i) risks related to the type of ecosystem, ii) risks related to interacting in an ecosystem, and iii) risks related to changes to and evolution of an ecosystem.

The issue is rounded out with a summary of the April TIM Lecture given by **Sorin Cohn** on the topic of enhancing competitive position through innovation beyond R&D.

Michael Weiss
Guest Editor

About the Editors

Chris McPhee is Editor-in-Chief of the *Technology Innovation Management Review*. Chris holds an MASc degree in Technology Innovation Management from Carleton University in Ottawa and BScH and MSc degrees in Biology from Queen's University in Kingston. He has over 15 years of management, design, and content-development experience in Canada and Scotland, primarily in the science, health, and education sectors. As an advisor and editor, he helps entrepreneurs, executives, and researchers develop and express their ideas.

Michael Weiss holds a faculty appointment in the Department of Systems and Computer Engineering at Carleton University in Ottawa, Canada, and is a member of the Technology Innovation Management program. His research interests include open source, ecosystems, mashups, patterns, and social network analysis. Michael has published on the evolution of open source business, mashups, platforms, and technology entrepreneurship.

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Evolution of Wireless Sensor Networks for Industrial Control

Arthur Low

> *The history of life is more adequately represented by a picture of 'punctuated equilibria' than by the notion of phyletic gradualism. The history of evolution is not one of stately unfolding, but a story of homeostatic equilibria, disturbed only 'rarely' (i.e., rather often in the fullness of time) by rapid and episodic events of speciation.*
>
> Niles Eldredge and Stephen Jay Gould
> (1972; tinyurl.com/ak34qt3)

Technologies evolve in a process of gradual scientific change, but the commercial application of technologies is discontinuous. Managers interested in technology evolution can integrate these contrasting ideas using a powerful theoretical framework, based on the concept of punctuated equilibrium from evolutionary biology. The framework, which enables the differentiation of the technical evolution of a technology from its market application, is used in this article to compare the two standards for wireless sensor networks (WSN) for industrial instrumentation and control: WirelessHART and ISA100.11a.

The two WSN standards are the product of two different market contexts, which have selected different minimum viable technologies for evolution in their respective niches. Network security issues present some important selection criteria. Both WSN standards implement security countermeasures against localized wireless network attacks based on the application of the AES encryption standard, but some specific security threats – some local, others remotely launched – are only well-defended by the adoption of public-key cryptographic (PKC) protocols, which only ISA100.11a supports. This article concludes that the mainstream market potential of the Internet has influenced the evolution of ISA100.11a and will continue to demand that each WSN standard evolve in ways that are difficult to predict.

Introduction

Comparisons between the two standards for wireless sensor networks (WSN) for industrial instrumentation and control commonly view WirelessHART (WH; tinyurl.com/bblesph) and ISA100.11a (ISA; tinyurl.com/bba9gdp) as competing standards, and they tend to conclude that one standard is better than the other. Consider the titles of recent comparisons in two widely read industry trade journals: “WirelessHART Wins Standards Battle Against ISA100.11a” (*Control Design*, 2012; tinyurl.com/a35d3tw) and “ISA100.11a Completely Obviates the Need for WirelessHART” (*Petro Industry News*, 2007; tinyurl.com/a9ddkty). However, such comparisons are more likely confuse than educate the industry. The former article described "standards confusion" and fading hope within the industry for a convergence between WirelessHART and ISA100.11a. The goal of this article is to help relieve some of this apparent confusion in the control industry that may be the consequence of previous, “winner-take-all” technically-driven comparisons of the two WSN standards.

This article compares the two competing WSN standards for industrial control, not based on purely technical dimensions, but based on a theoretical frame-

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work of technology evolution, drawn from the technology innovation management literature. Thus, this article is a tangible application of theories and approaches to technology innovation. The theoretical framework enables the gradual evolution of WSN technology to be differentiated from its discontinuous commercialization in the automation and controls industries.

The article is structured as follows. First, the theoretical framework is introduced and its methodology is explained by referring to the development of wireless technology in the 19th and 20th centuries. Next, the two WSN standards – WirelessHART and ISA100.11a – are compared. The framework is then applied to differentiate each technology from its market application. Next, two market contexts are presented based on the networking and security differences of the two standards. Finally, conclusions are provided.

Theory of Punctuated Equilibrium

The following two perspectives on technological change appear to be inconsistent, and therefore hard to reconcile without a suitable theoretical framework: i) technology undergoes gradual and incremental scientific progress, and ii) the commercialization of the technology is both rapid and discontinuous. The theory of punctuated equilibrium, derived from evolutionary biology, offers a powerful theoretical framework (Adner and Levinthal, 2002; tinyurl.com/a5t62bx) to reconcile apparent inconsistency between the gradual change in underlying science and the discontinuous commercial applications of technologies. The theory was introduced to explain the inconsistency between the fossil record and Darwin's concept of gradualism. The inconsistency was resolved by noting that speciation events allowed the separate evolution of one population from its antecedent. Two critical features of speciation were observed. First, speciation is genetically conservative; it does not follow from a sudden genetic transformation of the population. Second, the distinctive growth of the new species following the speciation event is the result of the different selection environments.

The theoretical framework of punctuated equilibrium defines a method to identify the critical transition point when emerging technologies realize commercial importance. The analogue of a speciation event in technology is the application of existing technologies to a new domain. After the speciation event, major commercial impact may be observed if there are available resources and selection processes that drive rapid technological development to adapt to the environment featured in the new domain.

Framing technology evolution in terms of a speciation event allows a technology's technical development and its market application to be differentiated. This allows a manager responsible for a technology innovation to make better plans for R&D activity to match the needs for innovation and the available resources of a real market. Changes in an application's domain signal significant shifts that define different selection criteria concerning a technology's minimum viable functionality, such as an emphasis on specific critical functionality from the general prototype function and available resources to drive innovation.

Radically divergent technology and rapid technological change can follow a speciation event. The framework of punctuated equilibrium specifies that the nature and pace of technological change are driven by two elements of the selection process. First, the process of adaption begins when the prototype technology (with a minimum threshold viability) becomes adapted to the particular needs of the new niche. Second, resource abundance within the niche drives the pace of development, especially if the applicability of the technology in terms of more functionality or lower cost can extend to more mainstream markets.

When technology that emerges from its speciation event is ultimately able to successfully invade other niches, possibly including the original domain of application, creative destruction can occur, meaning that a new combination of technical and business-model innovation destroys the incumbent's capital.

Framing the evolution of wireless technology

The development of wireless technology offers an example of how the theoretical framework of punctuated equilibrium can be applied to the evolution of WSN technology for automation and industrial control.

Table 1 shows how the theory of punctuated equilibrium applies to the development of wireless communications in the late 19th and 20th centuries. Hertz developed wireless instruments to prove Maxwell's theories of electromagnetic (EM) waves, then Marconi selected Hertz's minimum viable EM equipment for the sending and receiving of radio wave signals over long distances. This was the speciation event.

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Table 1. Evolution of wireless technology

Technology	Domain	Selection	Resources	Outcome
EM Pulse	Science	Prove theory	Low	Instrument
	Commerce	Ship-to-shore communication	High	Vacuum tube
Vacuum Tube	Niches	Police radio	Moderate	Private radio
	Mainstream	High quality & low cost	Massive	Broadcast radio & TV

Abundant resources were applied to the niche for ship-to-shore communications. Transmitter power and receiver sensitivity were selected for improvements, which led to the development of the vacuum tube and the analog-electronics industry. Primitive tubes that enabled transmission and reception of low-quality audio (i.e, sufficient for understandable speech) were immediately selected for mobile radios for police and military applications. Over time, comparatively modest resources offered by the niche markets improved the audio quality. Eventually, massive resources were allocated by large corporations to develop and mass-market radio and TV broadcast technology.

Comparing WH and ISA

The Institute of Electrical and Electronics Engineers (IEEE; ieee.org) standard for low-rate wireless personal area networks (LR-PAN) is 802.15.4 (tinyurl.com/a3tdv54), which specifies the first two layers in the Open Systems Interconnection (OSI) model: the physical (PL) layer and the media access control (MAC), or data link, layer.

The PL operates with carrier sense multiple access with collision avoidance (CSMA/CA). WH and ISA use the 2.4 GHz band with 16 channels. The MAC layer specifies the frame with header, payload, and check fields for the reliability and integrity of the frame. The latest version of the MAC layer standard, 802.15.4-2006 (approved by the IEEE in 2012), adopts the ISA100.11a standard for network synchronization using time division multiple access (TDMA) with 10–14 mS variable time slots and three channel-hopping schemes.

Figure 1 shows that PAN networks can take on both star and peer-to-peer configurations, including full-function devices (FFD) and reduced-function devices (RFD).

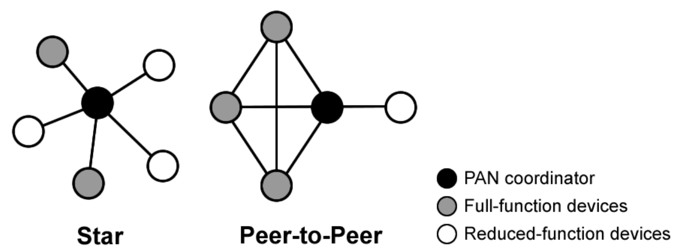

Figure 1. PAN network topology
(Adapted from: tinyurl.com/a3tdv54)

The network (star or peer-to-peer) is controlled by the PAN coordinator. Peer-to-peer networks enable “ad hoc” formation of a more complex network called a “mesh”. Mesh routing is a network (OSI layer 3) function, which is not specified by IEEE 802.15.4. Nevertheless, in the peer-to-peer network shown above, there are several routes from the PAN controller to the FFD node to its left. The distance from one node to another is measured in “hops”.

WH specifies a number of device types in its network, specifically gateway (G), security manager (S), network manager (M), access point (AP), field device (F) and a hand-held provisioning device (PD). ISA specifies system manager (M), security manager (S), gateway (G), backbone router (B), router (R), input/output node (IO), routing IO node, and a portable (P) device. These devices and their general connection diagrams are shown in Figure 2.

Redundancy is an important design consideration for critical industrial-control applications. Both networks show redundancy. In the WH network, G can connect to any F through either AP. In the bottom ISA network, redundancy is shown such that the GMS can connect to

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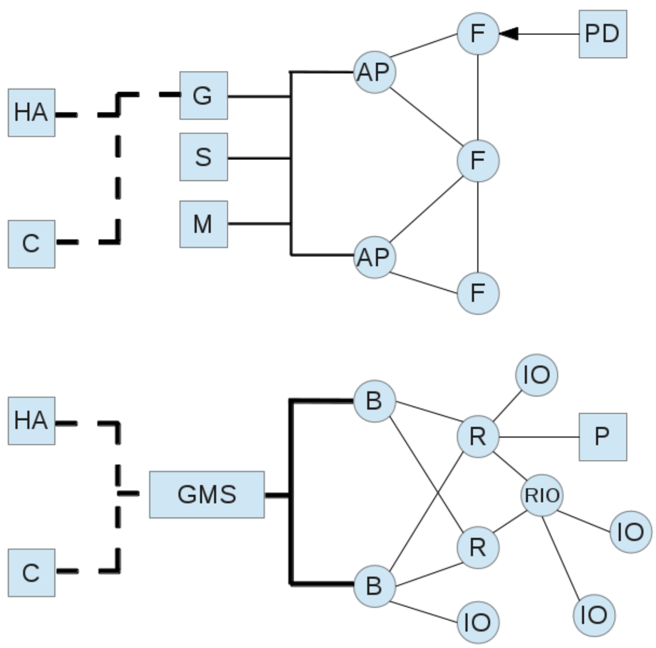

Figure 2. General network architectures: WH (top) and ISA

the RIO through any B and R node. The ISA network also shows a backbone network (solid thick line) connecting the GMS and the backbone routers.

In Figure 3, the OSI model is used in this article to compare the two WSN standards. The ISA100 Wireless Compliance Institute's depiction of its OSI stack (left) is shown beside the WH OSI stack (right). The layer abbreviations are shown between the ISA and WH stacks. Note that the ISA stack is based on several Internet Engineering Task Force (IETF; ietf.org) requests for comments (RFC) and the standards from IEEE and ISA.

Similarities and differences

Beginning at the physical layer (PL), both standards use IEEE 802.15.4 radios operating at 2.4 GHz, and at least passive neighbour discovery, channel hopping, and TDMA time-slots at the data link layer (DL).

The differences begin at the DL. WH supports a fixed 10 ms time-slot and just one channel-hopping scheme. ISA specifies 10–14 ms variable time slots, three channel-hopping schemes, and active neighbour discovery. The ISA network layer (NL) supports IPv6 addressing by adopting the IETF Internet Protocol version 6 (IPv6) over low-rate personal area networks (6LoWPAN) standard. Sub-net routing is also supported, whereas WH supports local routing based on HART addressing.

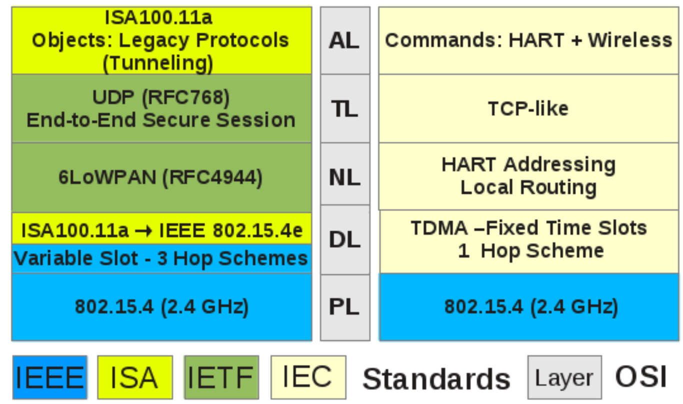

Figure 3. WH and ISA mapped to OSI layers

At the transport layer (TL), ISA is 6LoWPAN-compatible, based on UDP, whereas WH specifies a TCP-like (connection-oriented, reliable) data-transport mechanism. Both standards aim at efficiency of message passing between applications. The WH application layer (AL) is command-oriented (commands were added to HART commands to support wireless operation). WH commands can be aggregated. ISA is object-oriented at the AL. Object-based messages can be concatenated.

ISA supports 6LoWPAN

6LoWPAN enables the transport of IPv6 packets over IEEE 802.15.4 low-rate wireless personal area networks (LoWPANs). IEEE 802.15.4 frames are too small for the maximum size of an IPv6 packet. To support 6LoWPAN, between the NL and DL, header encapsulation, compression and fragmentation mechanisms were defined. As a result of 6LoWPAN compatibility at the NL and DL, ISA supports the development of backbone routers.

Security considerations

Both standards provide two layers of network security. The DL applies a message integrity check (MIC) in WH, whereas ISA supports several MIC or encryption security policies inherited from the IEEE 802.15.4 MAC layer. Based on these policies, ISA can selectively encrypt and authenticate the MAC payload. The use of several types of symmetric keys is presenting in Table 2.

A join key is defined in both standards to be used by the device to join the target network using an authorized password. The join key acts as a session key between the node and the network manager during the join process. In WH, the symmetric join key is transmitted to the node when the device is provisioned. ISA supports

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Table 2. WH and ISA key-management schemes

Key	WH	ISA	Function
Join	Encrypts	Authenticates	Enables node to join the network
Data Link	DL Key MIC (all nodes)	NL Key MIC / Encrypt (sub-net)	Written to node by security manager (SM)
	Join Key	Master Key	SM encrypts with the join key
Session	Network	Transport	Written to node by security manager (SM)
	Join Key	Master Key	SM encrypts with the join key
Global	Well-known	K_Global	Used to authenticate during join process
Master	N/A	Never transmitted	Generated by node and SM using PKC and provisioned credentials

symmetric and asymmetric keys. Using asymmetric keys, the symmetric keys used by the node can be regenerated without repeating the device-provisioning process.

A DL key is used by WH, whereas an NL key is used by ISA. The purpose is the same: to provide encryption between devices as the message "hops" along the network. But, the DL key is the same for all WH devices, because messages may traverse the entire network, whereas more specific sub-network keys can be defined in ISA.

Both WH and ISA support end-to-end security. A session layer (SL) key (session key) enables secure transfer between end points, at the TL for ISA and the NL for WH. ISA supports peer-peer secure sessions, say between a gateway and network device.

Key distribution and provisioning

A hand-held device is plugged into the WH node to provision it using only symmetric keys. The join key is written to the WH device to provision it for the specific network. The network manager can then write the NL key and the SL key (encrypted with the join key) to the new device after it joins the network.

ISA supports dynamic key distribution using asymmetric keys based on the principles of public-key cryptography (PKC). PKC enables over-the-air (OTA) provisioning, as well as automated "re-keying". The security credentials for each node are provisioned. Then, all keys are derived from the asymmetric master key (private key) that is generated inside each device using a secure key generation (SKG) process. Asymmetric SKG enables both devices to create a shared secret master key without ever transmitting the master key between nodes. The DL key and SL keys are then encrypted with the master key and written to the node.

WSN-based security threats

WH and ISA inherit threats common to all IEEE 802.15.4 WSN installations (Alcarez and Lopez, 2010; tinyurl.com/azkdux4). Generally, these threats can be mitigated by the installation of an intrusion detection system and by adopting the recommended countermeasures.

WH has two vulnerabilities that ISA avoids due to adoption of a PKC-based key-management scheme (PKC-KMS) as part of its suite of recommended countermeasures for IEEE 802.15.4 LR-WPANs. Although rarely applicable, WH is vulnerable to the Sybil attack (tinyurl.com/65mygp) if the security policy of the network does not specify the frequent updating of the NL and SL keys. WH is vulnerable to a sniffing attack, depending on the rate of provisioning of new nodes, which affects how fast the WH network can update its security credentials. ISA avoids sniffing attacks by using time-limited network and session keys. ISA prevents a Sybil attack by a strong challenge-response process that ensures the security manager issues unique contracts to all nodes, and by the periodic updating of all security credentials.

Framing the Evolution of WH and ISA

The framework of punctuated equilibrium defines a speciation event as the application of existing technology to a new domain. Using this theoretical framework, we start by considering what existing minimum viable technology was available for selection as an outcome of the evolution of electronics and computers.

The growth in complexity of computer programs led to the development of object-oriented software libraries. Open source development communities expanded on the proprietary technology-driven business models and have been major contributors to the development of the Internet. The Internet Protocol (IP) has expanded to IPv6 to enable uncountable numbers of interconnected devices. IPv6 has been further extended to low-rate personal area networks to produce 6LoWPAN, which essentially merges wireless mesh networks with the Internet backbone. Advances in symmetric and asymmetric cryptography and hashing algorithms have enabled robust end-to-end security to be applied effectively above the network layer and to the data link layer. Low-power wireless semiconductors and embedded software systems on chips enable self-organizing machine-to-machine mesh networks.

Table 3 shows the evolution of the base technologies that are the ancestors of WH and ISA. For example, starting in the left column, the general technology domain of electronics and computers was migrated to three new sub-domains: software, security and wired controls. In the case of the software sub-domain, the growth of software-program size led to increased software complexity that caused problems with maintainability, reusability, and reliability. Efforts to handle software complexity were therefore highly funded, and the outcome was the innovation of object orientation. The technology evolu-

Table 3. Evolution of WSN automation technology

Technology	Domain	Selection	Resources	Outcome
Electronics and computers	Software	Complexity	High	Objects Open source
	Security	Secure key generate	High	PKC
		Encrypt & authenticate	High	AES
	Wired controls	Industrial control	High	Sensors: HART + other standards
Internet	Machine to machine	Addressing	High	IPv6
Semi-conductors	Wireless	Low power Spread spectrum	High	IEEE 802.15.4
802.15.4 IPv6	LoWPAN	Low power reliable & IOT	High	6LoWPAN
Sensors 802.15.4 6LoWPAN Objects AES PKC HART + other standards	Wireless controls	HART Security	High	WH
	Wireless controls Internet	Industry standards Objects Security IPv6 LoWPAN OTA Provision	High	ISA

tion within the sub-domains of security and wired controls can be explained in the same way. The next two parent technology associations are for the Internet and semiconductors. The outcomes of these technologies were two new sub-species: Ipv6 network addressing and IEEE 802.15.4 low-power wireless personal area networking chips (LoWPAN). When these technologies mated, the offspring was 6LoWPAN. The last technology association is the cross-fertilization of a number of technologies that the framework identifies as the two speciation events that are the subjects of this article. WH was developed to adapt HART to the LoWPAN (wireless) domain. Resources were highly available and aligned to evolve WH. Multiple existing (and new) wired standards for industrial control and automation can directly use ISA to reach the LoWPAN domain.

Applying Market Contexts

Considering the difference between WH and ISA, there are two key market contexts that will drive innovation and channel resources that affect the pace and diversity of the evolutionary process unfolding:

1. **Heterogeneous Wireless Standards:** Heterogeneous wired-sensor installations can co-exist, but heterogeneous WSN standards based on IEEE 802.15.4 will compete and jam each other's spectra.

2. **The Internet:** The Internet is itself a rapidly evolving technology and applications ecosystem. The emergence of a WSN that can invade the Internet represents a mainstream opportunity.

Applying security considerations to these two market contexts, ISA offers defenses against sniffing and Sybil attacks, due to its PKC-KMS, which WH lacks. The implementation of a broad range of recommended countermeasures is essential for both types of WSN installations. Considering that 6LoWPAN is a parent technology of the ISA standard, clearly the ISA has enabled its standard to more easily adapt to the addressing requirements of the Internet with the WSN. Strong PKC-KMS is an important attribute of the ISA standard when considering Internet security.

Discussion

The framework of punctuated equilibrium requires recognition of a significant shift that defines different selection criteria for specific minimum viable functionality that must exist before it can be applied to the newly identified market niche. Industry has accepted WH, but the emphasis of the Internet as an application domain led to the selection of 6LoWPAN in ISA, which represents a major difference between the two WSN standards:

- WH extends the HART protocol to wireless by selecting the minimum viable functionality of IEEE 802.15.4-based WSN and symmetric-key algorithms for security.

- ISA extends the selection criteria of WH to include object orientation, 6LoWPAN compatibility, and asymmetrical cryptography.

Strong selection forces have created a speciation event for both WH and ISA by applying existing technology to new market niches. Each niche has applied different resources and emphasized different aspects of the technology to improve. Within those niches, innovations to WH and ISA have occurred at different paces, driven by differences in resource abundance and market demand for technological change.

The ISA niche invaded the original IEEE 802.15.4 niche. The inclusion of ISA MAC layer channel-hopping schemes and variable time-slots in the updated IEEE 802.15.4-2006 standard for LR-WPAN radios can now be seen as an important and possibly disruptive evolutionary event.

Conclusion

In this article, the framework of punctuated equilibrium was applied using a tabular method to compare the two WSN standards for industrial control. The method differentiated the gradual, continuous evolution of one or more antecedent technologies from their discontinuous and sometimes rapid commercial application inside several new sub-domains. This differentiation is called speciation. Two speciation events were defined as the establishment of two new, commercially important market niches for WirelessHART and ISA100.11a. Actors within each WSN sub-domain will select features of the technology for further evolution within the niche, which implies that they will evolve distinctly at a pace set by the resources available in each niche market. Technology innovators can identify opportunities by successfully analyzing what minimum viable technology the niche has selected for refinement. One such opportunity is the need for improved security features based on PKC technologies.

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This article can therefore make two specific conclusions about the evolution of the two WSN standards. First, ISA's support for IPv6 via 6LowPAN, more robust network security by application of PKC-KMS, and application-layer support for heterogeneous legacy wired standards is significant. The influence of the ISA standard on the IEEE 802.15.4-2006 standard, which the framework of punctuated equilibrium identifies as an invasion of the antecedent application domain, is strong confirmation of the robustness of ISA's new niche. Second, market forces will work to evolve adoption of WSN technology by these two considerations:

1. The likelihood that other legacy wired automation standards will follow the HART model by extending themselves to IEEE 802.15.4 or adopting the ISA standard.

2. The pace of development of each standard and the technological emphasis on improving minimum viable functionality by market selection processes in the WH and ISA niches.

Looking to the future, major resources will be applied to bring industrial plant intelligence into the mainstream of the Internet.

Acknowledgements

I would like to thank Professor Michael Weiss of Carleton University's Technology Innovation Management program for suggesting the use of the evolutionary framework for the comparison of the two standards. Also, I would like to thank Jayson Shiu of Suncor Energy for suggesting the comparison of the WirelessHART and ISA100.11a standards. A version of this article was presented at the ISA Calgary Show 2013 in Calgary, Canada, April 17–18, 2013.

About the Author

Arthur Low is the founder and Chief Executive Officer of Crack Semiconductor, a supplier of high-performance cryptographic silicon IP used in some of the most demanding security applications. Arthur has a number of patents in the field of hardware cryptography. He has worked for a number of IC startups as a Senior IC designer and Architect and gained much of his fundamental IC design experience with Bell-Northern Research in the early 1990s and with IBM Microelectronics in the late 1990s. Arthur has a BSc degree in Electrical Engineering from the University of Alberta and is completing his MSc degree in Technology Innovation Management in the Department of Systems and Computer Engineering at Carleton University.

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Keywords: technology evolution, punctuated equilibrium, wireless sensor networks, standards, WirelessHART, ISA100.11a, industrial control

Niche Formation in the Mashup Ecosystem

Michael Weiss, Solange Sari, and Nadia Noori

"The Web was originally designed to be mashed up. The technology is finally growing up and making it possible."

Aaron Boodman
Greasemonkey creator

Mashups enable end-users to "mix and match" data and services available on the web to create applications. Their creation is supported by a complex ecosystem of i) data providers who offer open APIs to users, ii) users who combine APIs into mashups, and iii) platforms, such as the ProgrammableWeb or Mashape, that facilitate the construction and publication of mashups. In this article, we argue that the evolution of the mashup ecosystem can be explained in terms of ecosystem niches anchored around hub or keystone APIs. The members of a niche are focused on an area of specialization (e.g., mapping applications) and contribute their knowledge to the value proposition of the ecosystem as a whole. To demonstrate the formation of niches in the mashup ecosystem, we model groups of related mashups as species, and we reconstruct the evolution of mashup species through phylogenetic analysis.

Introduction

Mashups are situational applications that combine services provided by third parties through open APIs, as well as user-owned data sources (Matera and Weiss, 2011; tinyurl.com/ooarpku). A simple example of a mashup is an application that shows photos uploaded to Flickr on a map provided by Google Maps. The creation of mashups is supported by a complex ecosystem of interconnected data providers, users, and mashup platforms (Yu and Woodward, 2008: tinyurl.com/nuxvdhe; Weiss and Gangadharan, 2010: tinyurl.com/pzcvueu). In our own previous work we have examined the structure and evolution of the mashup ecosystem (Weiss and Gangadharan, 2010; tinyurl.com/pzcvueu), and mashup speciation (Weiss and Sari, 2011; tinyurl.com/puv9ksh).

Our goal in this article is to explain the evolution of the mashup ecosystem through the lens of the speciation. Earlier research on technology evolution (Adner and Levinthal, 2002; tinyurl.com/a5t62bx) has shown that the emergence of new technologies can be understood by tracing the evolutionary paths of technologies. By making visible how mashups can be "derived" from one another, we can provide data providers with a deeper understanding of future trends, users with templates on which to build their own mashups, and platform providers with an opportunity for building new types of tools. The article provides evidence of the formation of niches within the mashup ecosystem that are anchored around hub or keystone APIs, and it offers techniques for analyzing niche formation based on phylogenetics, the field that studies evolutionary relationships between organisms (tinyurl.com/2zl2fk).

First, we review related work on recombinant innovation, ecosystems, and technology evolution. Then, we describe our research method and report on our findings on niche formation in the mashup ecosystem. We conclude the article with a discussion of our findings and areas for future work.

Related Work

Recombinant innovation
Innovation can be described as a process of recombination, in other words, the construction of new ideas from existing ones (Hargadon, 2002; tinyurl.com/qb42wvm). The notion of recombinant innovation is closely linked to that of modularity, which allows the creation of new

products by mixing and matching components (Ethiraj and Levinthal, 2004; tinyurl.com/otufwwu). Imitation is one of the primary means of innovation (Bentley et al., 2011; tinyurl.com/nqf3gnm). When developers are creating new mashups, they often start with another mashup as a "blueprint" for their own mashups (Weiss and Sari, 2011; tinyurl.com/puv9ksh). Simulation models confirm that mashup development is largely the result of a copying process (Ethiraj and Levinthal, 2004; tinyurl.com/otufwwu).

Ecosystems
In an ecosystem, value is co-created by ecosystem members who both collaborate and compete (Thomas and Autio, 2012; tinyurl.com/ou57a6e). Research on the mashup ecosystem has found that the distribution of API use follows a power law, implying that the ecosystem has a small number of hub APIs that provide the base functionality for a large number of complementors (Weiss and Gangadharan, 2010; tinyurl.com/pzcvueu). Hubs naturally emerge in ecosystems (Thomas and Autio, 2012; tinyurl.com/ou57a6e). These hubs provide the stable common assets for the mashup ecosystem. Co-creation of new functionality in the mashup ecosystem is anchored around those common assets.

As observed by Hagel and colleagues (2008; tinyurl.com/njshs49) for innovation ecosystems, these hubs can be grouped into multiple tiers of keystones. The success of an ecosystem requires providing access to information on the innovation architecture, participating in standardization efforts, as well as investing in the providers of complements (West, 2006; tinyurl.com/8x8byvv). These activities, performed by a focal company, facilitate cumulative innovation. An example is Google's ecosystem (Iyer and Davenport, 2008; tinyurl.com/3954du2). At its core is Google's vast computing infrastructure that enables Google to leverage third-party innovation while maintaining architectural control.

Technology evolution
Adner and Levinthal (2002; tinyurl.com/a5t62bx) study the emergence of new technologies through the lens of biological speciation. They define speciation as the separation of one evolving population from its antecedent population. Speciation allows populations to follow different evolutionary paths. There are two processes at work: adaption (when technology becomes adapted to the needs of a particular niche) and resource abundance (how many resources are available in a niche to sustain the innovation).

Based on mechanisms of speciation and extinction, Weiss and Sari (2011; tinyurl.com/puv9ksh) describe an evolutionary model that generate clusters of mashups, that is, niches in the mashup ecosystem, and they estimate the diversification of the mashup ecosystem over time. The model represents a mashup as an individual of an evolutionary species. They reconstruct the evolution of mashups through phylogenetic analysis.

Research Method

Data collection
The data for our study was collected from the ProgrammableWeb (programmableweb.com), a repository of open APIs and mashups. There are other websites that provide similar services, such as Mashape (mashape.com); however, the ProgrammableWeb provides the most comprehensive collection. It should be noted, though, that the ProgrammableWeb only lists publicly accessible mashups; internally used enterprise mashups are not listed.

The extracted data was used to produce datasets for the population of APIs and mashups in the mashup ecosystem. The API dataset included the name, publication date, and category of each API, and the mashup dataset included mashup name, publication date, tags, and APIs used. The sampling period was from September 4, 2005 (i.e., the inception of the mashup ecosystem) to January 22, 2013, and it includes 2656 days. Over this time period, a total of 8245 APIs (of which 1186 APIs were used in at least one mashup) and 6868 mashups were published in the repository.

Data analysis
To identify hub APIs, we compute the contributions of each API to mashups and rank them by the number of mashups they contribute to. We then determine the set of APIs that is responsible for one third of the contributions to mashups. (This cutoff is chosen according to Bradford's law [tinyurl.com/q5mzx6j]). This process provides a set of candidate hub APIs to be examined more closely by constructing phylogenetic trees (tinyurl.com/qnxaar) in the next stage of the analysis.

To assess the relative impact that hub APIs have on the mashup ecosystem over time, we also compute their cumulative contributions. These curves will have the typical S-shape of an adoption cycle (Rogers, 1983; tinyurl.com/ntrq2f6). The inflection points in the S-curves mark events of significant interest to understanding the evolution of the ecosystem.

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Finally, we reconstruct the evolution of the mashup ecosystem by constructing a phylogenetic tree of mashup species. A phylogenetic tree captures the evolutionary relationships between species of mashups. The tree was estimated using the neighbour-joining method (Gascuel, 1997; tinyurl.com/og6o4yl), as implemented in the ape library (ape.mpl.ird.fr) in the statistics package R (r-project.org). A mashup species is a group of similar mashups.

Similar mashups will appear in related branches of the tree. The similarity of two mashups can be computed as the overlap in their APIs using the Jaccard index (Weiss and Sari, 2011; tinyurl.com/puv9ksh). Each mashup can be represented as a set of APIs. For example, given two mashups m1 = {Google Maps, Flickr} and m2 = {Flickr, Amazon eCommerce}, the similarity is 1/3 = 0.33, because both mashups share Flickr and the total number of elements is 3.

Findings

Growth of hub APIs

Table 1 lists the candidate hub APIs and their contributions together with their date of introduction and category assigned to them on submission.

The graph in Figure 1 shows the cumulative contribution of each API. Initially, adoption of an API is low. This phase is followed by a period of steep growth and subsequent saturation. Some of the curves (e.g., Google Maps) only show the steep growth and subsequent saturation portions of the S-curve. Here, we can assume that the early stages of adoption precede the creation of the ProgrammableWeb. In other cases (e.g., Twilio), the whole adoption cycle is captured within the graph. The growth stage is when an API will make its greatest impact on the ecosystem. These are periods where one would expect “bursts of innovation” (Adner and Levinthal, 2002; tinyurl.com/a5t62bx) driven by this API.

Table 1. Hub APIs and their contributions to mashups

Core API	Contribution	Date Published	Category
Google Maps	2437	2005-12-05	Mapping
Twitter	759	2006-12-08	Social
YouTube	656	2006-02-08	Video
Flickr	615	2005-09-04	Photos
Amazon eCommerce	416	2006-04-04	Shopping
Facebook	392	2006-08-16	Social
Twilio	353	2009-01-10	Telephony

Niche formation

Expecting that niches are anchored around hub APIs, we constructed phylogenetic trees centered on those APIs to identify characteristics of the niches. In Figure 2, we indicated each cumulative 1000 mashup increment by a vertical line to allow cross-referencing between the evolution of hub APIs and the APIs in each niche.

As we examine these trees, we observe that the impact of hub APIs varies with time. API dominance and complementarity of APIs are some of the interesting observations we can make. For instance, in Figure 2a

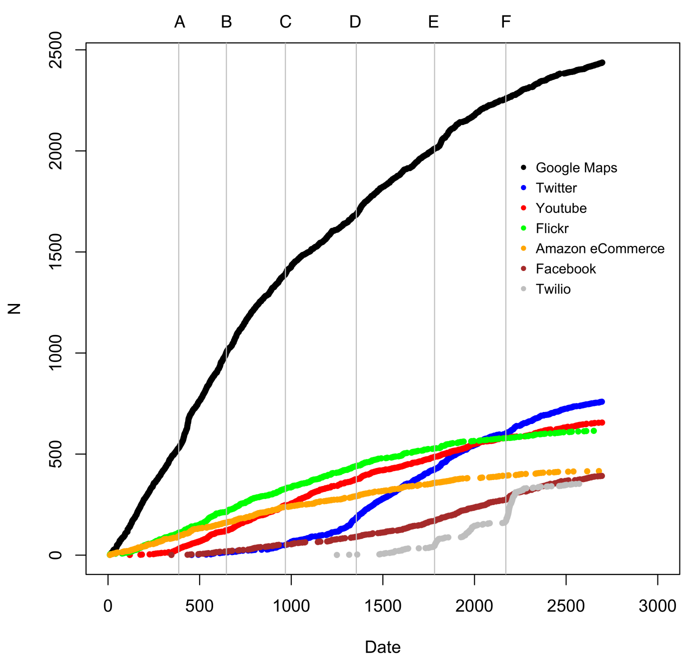

Figure 1. Contributions of hub APIs over time. Date is the number of days since inception of the mashup ecosystem. N is the number of mashups an API contributes to. Vertical lines marked with capital letters indicate the cumulative total number of mashups in 1000 increments.

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we can observe the initial dominance of Google Maps, as represented by a cluster of mashups that only use Google Maps. Later, as shown in Figure 2b, the clusters become more evenly distributed, because there are more clusters with APIs that complement GoogleMaps, such as Twitter and YouTube, or other APIs by Google, such as GoogleSearch.

One way to understand the impact of hub APIs on the evolution of the mashup ecosystem is to align growth stages in their S-curves (see Figure 1) with the phylogenetic trees for the corresponding time window. Figure 3 offers a more detailed perspective of each of the APIs complementing Google Maps past the 5000 mashups' mark (E). It shows the phylogenetic trees for Twitter, YouTube, and Twilio. Each of these APIs creates a niche within the mashup ecosystem, where it drives the evolution of this niche as its hub API. A similar analysis can be conducted within each of those niches. We can identify sub-niches such as the niche anchored around Facebook in the Twitter niche (Figure 3a), and Last.fm in the YouTube niche (Figure 3b).

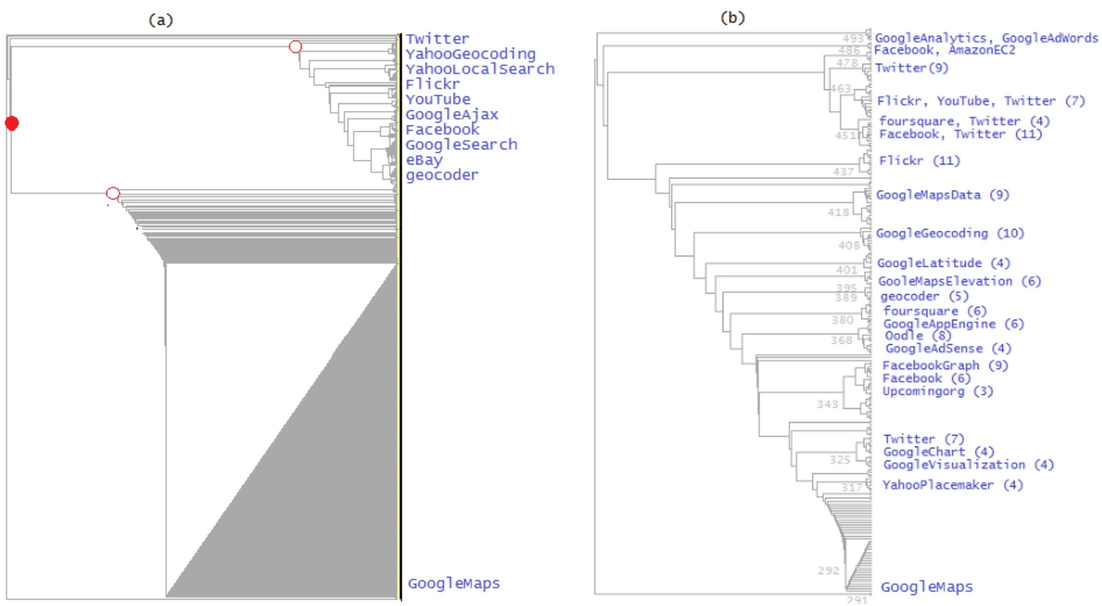

Figure 2. Phylogenetic trees comparing Google Maps API evolution (a) before and (b) after 1727 days. This date correspond to 5000 mashups (marked with an E in Figure 1).

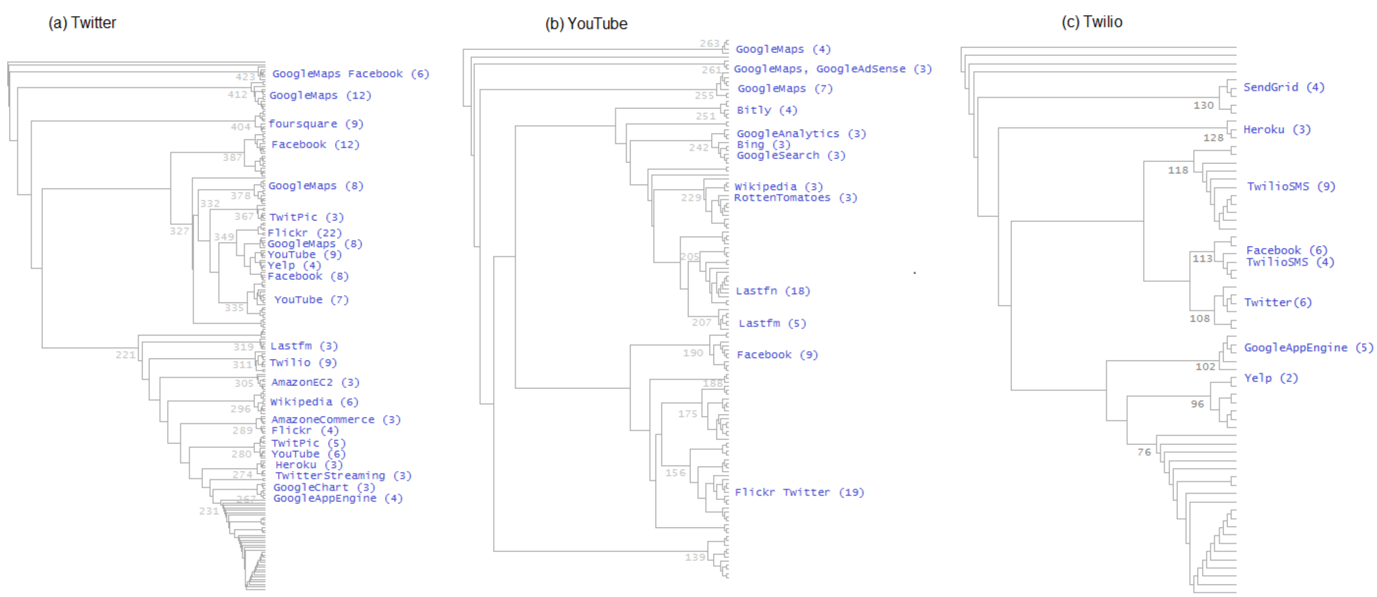

Figure 3. Phylogenetic trees of the Twitter, YouTube, and Twilio niches after 1727 days.

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Conclusion

Our research introduces a new methodology, based on phylogenetic trees, to analyze the mashup ecosystem. Phylogenetic trees allow us to trace the evolution of mashups from simple mashups to complex combinations of APIs, and to identify hub or keystone APIs around which new mashups are constructed. We can, thus, describe the evolution of the mashup ecosystem in terms of ecosystem niches formed around those keystone APIs, and niches within those niches. This model allows API providers and mashup developers to gain a deeper insight into future trends and opportunities.

Future research can explore a new generation of mashup directories that allow developers to browse a "tree of life" of mashups and to discover new opportunities for mashups. Such a directory could also be used by providers to learn about emerging needs for new APIs. Furthermore, we can apply the methodology to different areas. Of particular interest to readers of this journal is the possibility of understanding the evolution of open source projects using trees based on project dependencies.

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Rapid Prototyping Using a Configurable Platform

Antonio Misaka

> *“The only good idea is an implemented idea... that stays implemented!”*
>
> William C. Byham
> Entrepreneur, author, and organizational psychologist

This article describes an approach for speeding up the development of web applications using a configurable platform. The core idea of the approach is that developers can implement customer requirements by configuring platform components, instead of writing large amounts of “glue code” to wire the components together. This approach reduces the amount of glue code that still needs to be written and maintained, it shortens the time it takes developers to create a prototype, and it makes it easier for glue code to be reused in the future. It also allows developers to experiment with different configurations of platform components in order to find the configuration that best meets the customer's requirements. Developers are also able to manage a larger variation in customer requirements.

Introduction

Web applications are commonly assembled from a number of existing components that are combined together to support a custom business process. These are components such as Drupal (drupal.org) and SugarCRM (sugarcrm.com), which provide commonly used functionality for content management and user-profile management. The code that connects the components is known as “glue code” (tinyurl.com/q3vu3hz). Because this code is very specific to the assembled components, it can be difficult to maintain and reuse.

This development approach can best be described as “clone-and-own” reuse: a new application starts out by duplicating glue code from a previous application (tinyurl.com/pcruf2h). Code duplication causes significant maintenance problems. If any errors are subsequently found in the original code, they will need to be fixed in every copy. The match between the needs of the new and the old application is also often not perfect. The duplicated code often contains “orphaned” code that does not serve any purpose in the new application.

At the same time, the applications created often only differ in minor details, and thus much time is wasted by developers modifying and creating glue code and learning about new component APIs (tinyurl.com/6abeyab). A more systematic approach to selecting components and creating glue code is called for – one that reduces the amount of unnecessary glue code. Application developers could learn from the discipline of software product-line engineering (tinyurl.com/ps7wyob), which is concerned with the systematic creation of common assets and methods for enabling reuse across products in a product line. This approach is not yet used widely for developing web applications, but the benefits of using a software product-line engineering approach are threefold: i) the resulting applications are more maintainable, ii) time is saved when developing the application as a result of reuse, and iii) the details of using a specific component can be hidden from the developer behind common interfaces.

Box 1 provides examples of business processes that share many of their requirements, and could benefit from a software product-line approach.

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Box 1. Examples of business processes with similar requirements

Tony, Fred, and Bob are business owners with very similar needs:

- Tony wants to run a promotion for his restaurant. When diners pay their bill, they should also receive a printed ticket that enters them into a draw for a prize. At the end of the promotion period, the winning ticket numbers are announced on a board in the restaurant. Diners with a winning ticket can redeem it at the restaurant.

- Fred runs a construction company and wants to generate leads for his business. Potential customers can enter their email on the company's website, and they will be sent an email with a ticket that also enters them into a draw for a prize. At the end of the promotion, a winner will be selected and notified by email. The winner can print their ticket and redeem it by visiting the construction company's office.

- Bob is the owner of an independent bookstore and wants to increase the loyalty among his customers. Customers can receive a discount on future purchases if they register their email on the store's website. When customers make a purchase, they can enter the number of their sales receipt on the website, and they will receive a ticket worth 10% of the money they spent, which they can redeem at their next purchase.

Each of our three business owners approaches Tickets R Us to develop a custom application that implements their business processes. Traditionally, Tickets R Us might have built an application for Tony, chosen appropriate components – such as platforms for maintaining a database of tickets, printing a barcode on a ticket, and scanning the barcode – and wired them together using glue code. When creating Fred's application, Tickets R Us would have started with the code developed for Tony, added a new feature to send a ticket via email, and made tweaks to the existing code. Similarly, when creating Bob's application, reuse would be limited to a clone-and-own approach.

In order to apply the software product-line approach to web applications, two problems need to be overcome: i) how to reduce the amount of “glue code” required to wire the components together, and ii) how to hide the details of specific components from developers. The first problem can be addressed by creating a configurable platform that contains the reusable components (also known as common assets). A large part of the glue code that would otherwise have to be created can be replaced by specifying a configuration of platform components.

The second problem can be addressed by raising the level of abstraction at which developers write code that interacts with specific components. However, the second problem can really be considered a subproblem of the first one: a configurable platform would be of little use if developers had to have detailed knowledge of specific components.

This primary audience of this article are companies like our hypothetical company Tickets R Us who need to create more maintainable applications and achieve a higher degree of reuse.

The rest of this article first offers a closer look at the problem of raising the level of abstraction at which the glue code interfaces with components. It then describes the architecture of a configurable platform that increases the level of abstraction at which web applications can be built. Next, it outlines a process for creating a configurable platform that builds on the lessons from software product-line engineering and early requirements analysis. The article concludes with a discussion of managerial implications.

Raising the Level of Abstraction

Glue code that developers write to wire together components is hard to maintain for a number of reasons. One reason is that there is a lot of it: the more code there is, the harder it is to maintain. The other reason is that glue code tends to be very specific to the components that are being assembled. On top, glue code is likely to be “reused” in an improper manner from one application to the next; this is the problem that we referred to earlier as clone-and-own.

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The first part of the solution to these issues is to create a configurable platform. When using a configurable platform, developers do not need to write as much glue code. In the next two sections, we outline an architecture and process of constructing such a configurable platform.

The second part of the solution involves raising the level of abstraction at which developers interface with components. If developers do not apply proper constraint, the glue code can become very dependent on specific details of the components used. Not only does this lead to more complicated glue code, but it also limits the opportunities to replace the components with other functionally equivalent components, should this become necessary later. For example, the glue code to send emails to customer should ideally be the same irrespective of which protocol is being used to access emails.

This dependency is a well-known problem when programming user interfaces, where the application code and user-interface code can become tightly intertwined. As in that case, decoupling the glue code from the components can help create code that is significantly easier to understand and maintain. In general, decoupling can be achieved by defining interfaces that abstract the functionality of components with similar functionality into a common set of operations, and requiring developers to invoke the components only through those operations. It is not incidental that creating such common interfaces creates a “language” that is much closer to a business owner's model of the domain.

For example, in the Tickets R Us example, business owners will be used to specifying the requirements for what a ticket should show in terms of concepts such as ticket numbers, barcodes, and expiration date. Those concepts are a natural part of the language used by anyone who intends to use tickets for a promotion. These users are less likely to be familiar with expressing this information in the format required by a particular barcode component. Creating these common interfaces thus closes the “gap” that exists between how business owners express their requirements and the way developers think about writing glue code.

Architecture of the Configurable Platform

Figure 1 shows a proposed architecture of the configurable platform. Users of the platform (the business owners) are shown as subscribers on the top left. The configuration of platform components for each application can be specified in a configuration table. A configuration is a list of services that can be invoked by each application and specifies the values of configuration parameters for each service. Examples of services are Email, Login, or Ticket Generation.

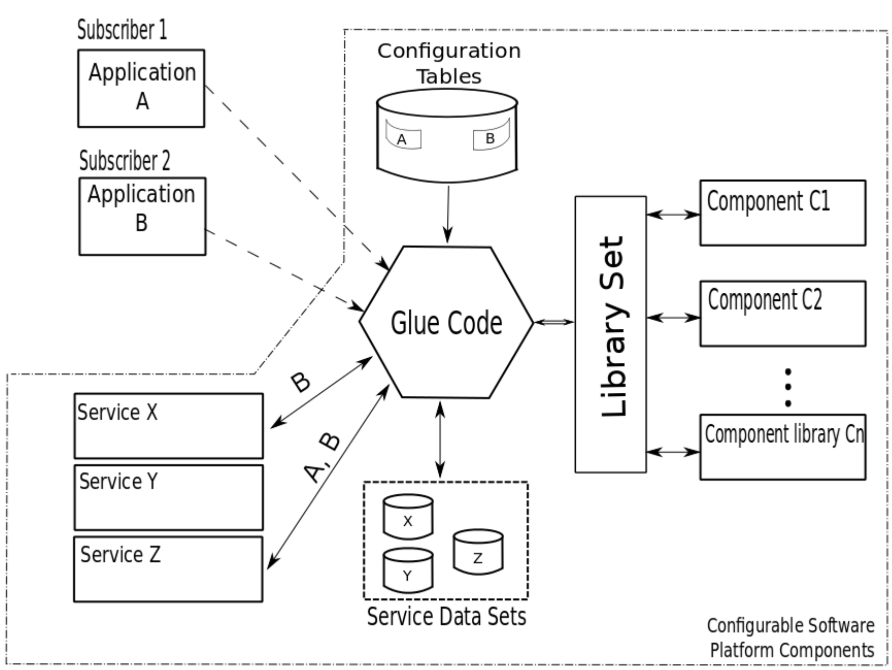

Figure 1. Architecture of the configurable platform

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Each service provides an abstraction for platform components with similar functionality and can be configured through parameters. For example, whether or not a ticket should be sent by email is a configurable parameter of the Ticket service. If the parameter is set to sending email, the corresponding glue code that invokes the Email service will be executed. The type of barcode to use on the ticket is another parameter that can be specified in a configuration.

Process

This section describes a process for creating a configurable platform and building applications based on this platform. The benefits of this approach are:

1. **It raises the level of abstraction:** Software platform configurations are defined in the language of the business owner (also known as the domain level), not at the implementation level.

2. **It simplifies configuration:** Glue code that specifies a selection of components and sets configurable parameters is easier to reuse than component-specific code.

3. **It makes reuse more systematic and efficient:** Glue code can be reused across multiple applications through shared services, not in the form of "clone-and-own" reuse.

A domain is an area of knowledge or expertise. It typically reflects the business owner's mental model of a domain. In software product-line engineering, a distinction is made between domain engineering and application engineering. Developing a platform that contains the core assets is referred to as domain engineering, and developing products from the platform is referred to as application engineering (tinyurl.com/p6xn7zh). Assets created during domain engineering are reusable, whereas the assets created during application engineering tend to be specific to a particular application, unless they recur across applications, in which case they should be turned into reusable assets to avoid future duplication of work.

The requirements are captured in the form of form of goals and expectations (goal models) and business process descriptions (scenarios). In the research we conducted, those models are represented in user requirements notation (URN). However, for sake of the exposition, we will not go into details of this notation here, but refer the interested reader to the project website (usecasemaps.org). For readers familiar with use cases and the unified modeling language (UML; tinyurl.com/anyno), we might add that URN bridges between use cases and object models in the UML.

The process comprises five steps:

1. Modelling domain requirements

- Gather user requirements in the form of goals and expectations (goal models) and business process descriptions (scenarios) by interviewing the business owners.

- A goal model is created for each business owner or a group of business owners that share the same functionality. A specific key identification is created for the configuration table.

- Links between goal models and scenarios are captured.

2. Identifying commonalities and variabilities in the requirements model

- Identify common and variable elements in goals models and scenarios. These represent the configurable features of the system.

- Commonalities are all those elements repeated in each model (goal and scenario models), and variabilities are elements that are unique to a model. Variabilities are candidates for configurable variations in the features provided by the platform. For a variation to be supported by the platform, it must generally occur more than once in the models.

- Identify candidate components that can provide those features. Those components can be selected by a developer when implementing the requirements. Identify parameters through which the components can be configured.

3. Modelling application requirements

- Create a model application using all the necessary elements to create the configurable platform. Existing software components, both third-party components and internally developed components, are possible candidates for reuse in the configurable platform. The model should incorporate the requirements to be satisfied and all functionalities expected by the configurable software platform.

4. Identifying existing components

- Match components in the scenario models against the available software components.

- Identify configuration parameters to be included in the configuration tables.

5. Binding variabilities to components

- Develop and implement the necessary glue code to run an application. The developer now has all the necessary information to build a prototype using the selected set of components.

- Test the prototype and verify it with potential customers.

Box 2 provides an example of the first two steps of the process.

Figure 2 shows how the architecture from Figure 1 was instantiated for the Tickets R Us example (steps 3 to 5). Note that, for purposes of illustration, some details have been removed from the diagram.

Conclusion

If a company plans to create a series of web applications in the same application domain, it should consider building a configurable platform first. A configurable platform offers two advantages over the traditional "clone-and-own" approach: i) developers save time when building applications with similar functionality and can take on more projects, and ii) it raises the level of abstraction at which web applications can be built. The approach also reduces the translation errors developers can make when mapping high-level user requirements to low-level application details. Creating a configurable platform does not come without initial expense, however, but will pay off after a few applications.

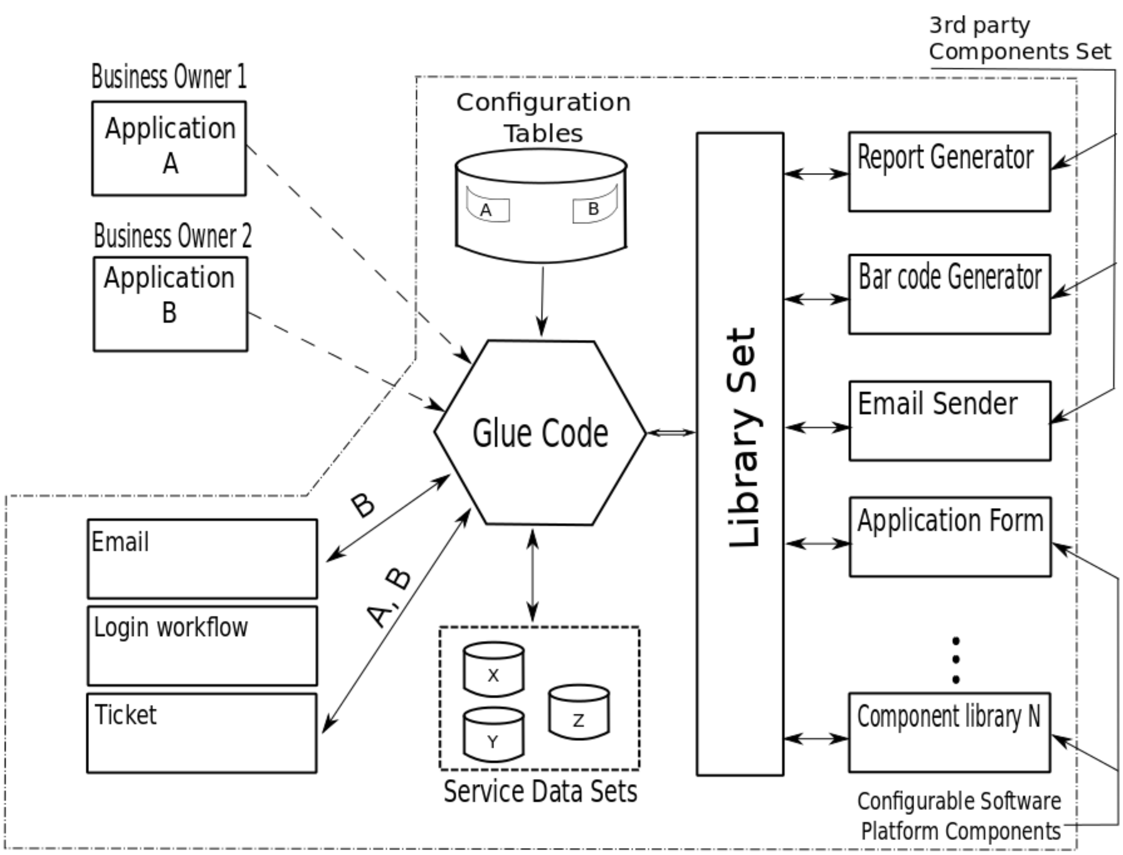

Figure 2. Instantiation of the architecture for the example

Box 2. Applying the process to the Tickets R Us example (steps 1 and 2)

In the first step (modelling domain requirements), we capture the business owner's domain requirements in terms of their goals and business processes. Here are samples of the requirements in plain language:

- Tony, the restaurant owner, wants to use promotions to get diners to return. His needs include the ability to generate tickets, print them, and allow winners to redeem tickets for a prize.

- Fred wants to use promotions to generate leads for his construction company. In addition to being able to generate tickets, he needs to be able to collect email addresses from potential customers.

- Bob wants to increase his customers' loyalty by giving them discounts on future purchases. He also needs his customers to be able to enter their sales receipts on the bookstore's website.

Note that "wants" indicate goals and "abilities" indicate steps in a business process.

In the second step (identifying commonalities and variabilities in the requirements model), we look for what is common among the models and in which ways they differ. For example:

- All business owners want to increase their sales through promotions.

- They want to collect information about their customers, but plan to do so in slightly different ways (sales receipts for Tony and Bob, and email addresses in Fred's case).

- They all need to generate tickets, but in some cases (Tony) the tickets are generated at the point of purchase, and in the other cases (Fred and Bob), they are generated via a website.

- All tickets have barcodes, but there can be different types of barcodes.

- All business owners need to allow winners to redeem their prizes, but they use different ways of informing winners (through a board for Tony, or via email for the others).

From this information, we can identify common and variable features, choose candidate components that provide those features, and identify configuration parameters for the components.

Examples of common features that all business owners require include:
- prompting users to enter data
- generating tickets
- selecting the winning tickets
- redeeming winning tickets

Examples of variable features that require different implementations for different business owners, or that only some business owners have asked for include:
- supporting multiple types of barcodes on tickets
- sending emails to winners
- registering and logging in customers

Examples of candidate components include:
- PHP Barcode to create and read barcodes
- PHP Mailer and SMTP in PHP to send emails
- MyDB database framework for PHP
- Tickets R Us' own components to generate random ticket numbers
- Tickets R Us' own components to check submitted tickets

Examples of configuration parameters include:
- text to display on the tickets
- barcode type
- flag whether to send emails to customers
- expiry date of the promotion

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Keywords: web applications, rapid prototyping, configurable platform, requirements analysis, software product-line engineering

Navigating Risk When Entering and Participating in a Business Ecosystem

Derek Smith

> *“The biggest dangers to a company are the ones you don’t see coming. Understanding these threats – and anticipating opportunities – requires strong peripheral vision.”*
>
> George S. Day & Paul J.H. Shoemaker
> (tinyurl.com/c7x75jt)

Entrepreneurs typically have limited resources during the start-up phase of a business. Business ecosystems are a strategy for entrepreneurs to access and exchange many different aspects of value, resources, and benefits. However, there may be business risks for entering a particular type of ecosystem, and further risks may be encountered after entering and participating in a business ecosystem. These risks are significant and can inhibit a startup's growth. In this article, the literature on business ecosystems is reviewed as it relates to risk to discover insights of relevance to entrepreneurs, top management teams, and business-ecosystem operators. First, the published research is organized into two streams: i) risks relating to categories of business ecosystems, and ii) risks relating to participating in business ecosystems. Then, the problem is abstracted to develop a potential strategy for managing these risks, which features a pre-entry inspection followed by real-time resource management. Finally, five recommendations are offered for entrepreneurs seeking to enter and participate in business ecosystems.

Introduction

Entrepreneurs must overcome significant challenges when starting up a company. They often face limited funding, a lack of resources, and a broad range of technical challenges. Creating foundational technology is time consuming, and it can be wasteful. Business ecosystems can help entrepreneurs, but a proper approach is key to providing value to the business. If the approach is mishandled, it can create additional challenges for the entrepreneur.

Entering into a business ecosystem is a powerful way to address these start-up issues by providing access to resources, foundational technology, customers, and alliances. Peltoneimi and Vuori (2004; tinyurl.com/cwtd63x) define a business ecosystem as: “… a dynamic structure which consists of an interconnected population of organizations. These organizations can be small firms, large corporations, universities, research centers, public sector organizations and other parties, which influence the system … to include a population of organizations. Business ecosystem develops through self-organization, emergence and co-evolution which help it to acquire adaptability.” A business ecosystem includes both cooperation and competition: it is an environment characterized by both opportunity and risk.

An entrepreneur must be able to navigate risk before and after entry into a business ecosystem; otherwise, these risks could create a multitude of more serious challenges at a time when the startup is vulnerable. “For many companies, however, the attempt at ecosystem innovation has been a costly failure. This is because, along with new opportunities, innovation ecosystems also present a new set of risks – new dependencies that can brutally derail a firm’s best efforts.” Adner (2006; tinyurl.com/bpj4syf).

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Entrepreneurs need to identify and understand the categories of business ecosystems, the stage of ecosystem evolution, and the associated participation risks. Early identification of the main actor – or keystone (Iansiti and Levien, 2004; tinyurl.com/bkg9vfl) – in the business ecosystem is also important. They also need to anticipate what risks they will be exposed to at two different points in time: before and after entering a business ecosystem. However, business ecosystems are a relatively new area of research, and therefore, the research into their specific risks is limited and cannot be sufficiently generalized to help entrepreneurs make decisions. Here, we ask: "What are the different types of risk in a business ecosystem, and how should an entrepreneur identify these risks"?

This article makes four contributions. First, it argues that entrepreneurs should consider business ecosystems as a viable option for startups. This argument complements the conventional perspective of business ecosystems as a means to share value and resources. Second, it identifies twelve published research articles on business ecosystem risks and summarizes their contents. Third, it distinguishes between business ecosystem category risks and participation risks. Fourth, it provides five recommendations to entrepreneurs seeking to effectively enter and participate in business ecosystems.

The body of this article is organized in three sections. The first section provides an overview of the research method, includes a review of the literature on business ecosystems as it relates to risk. The second section provides an abstraction of a business ecosystem into a dynamic constantly changing environment characterized by both risk and value to identify a broad solution to the problem. The third section provides recommendations for entrepreneurs. A final section concludes the article.

Literature Review

The literature review of business ecosystems began with a search in the Business Source Complete (tinyurl.com/22teqry) database on the keyword "business ecosystem". When restricted to the author-supplied-keyword field and full-text scholarly journals, the query identified 33 individual articles, with the earliest publication in 2001. A review of the abstract and introduction of the 33 articles identified a subset of 8 articles about business ecosystem categories and risks. The references of these articles were examined and 4 additional articles were added to this set for a total of 12 articles. Articles unrelated to categories and risks of business ecosystems were set aside.

The 12 articles were published in 10 different journals and conference proceedings. Two journals – the *Harvard Business Review* and the *Strategic Management Journal* – published two articles each from the set. The journals vary widely in disciplinary focus, including management, business, strategy, leadership and marketing.

The 12 articles were organized into two different streams: i) risks associated with business-ecosystem categories and ii) risks associated with participating in business ecosystems. Organizing the literature in this way revealed insight into business-ecosystem risks. Table 1 and Table 2 summarize the field settings, research designs, and unique contributions of the articles in each literature stream.

Risks associated with a category or type of business ecosystem

There are three articles summarized in Table 1 that relate to business-ecosystem categories. Purdy and colleagues (2012; tinyurl.com/bs9n5h2) identify three categories of business ecosystem: i) harbor and fleet, ii) demand forum, and iii) multivalent sourcing. In the harbor and fleet (platform) ecosystems, the harbor firm provides underlying or foundational resources and the fleet of companies gain access to the harbor and resources. Example harbors include Amazon (amazon.com) and Athenahealth (athenahealth.com), which offers cloud-based administrative services to medical practitioners. A demand forum ecosystem extends markets for suppliers and provides wider choices to customers. Examples include Yipit (yipit.com), a company that brings together local deals from many different Internet sources, and One Block Off the Grid (1bog.org), a community to attract a critical mass of buyers to negotiate a mass discount for solar panels. The multivalent sourcing category relates to acquiring materials, talent, and capital for production by creating economies of scale through the Internet. An example is Napkin Labs (napkinlabs.com), a crowdsourcing consulting company. Risks associated with harbor and fleet ecosystems relate to losing intellectual property rights. Risks with demand forum and multivalent sourcing ecosystems relate to business-model replication in local markets. Additional risks include complexity of relationship management and surrendering control.

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Table 1. Summary of literature on risks associated with business-ecosystem categories

Author (Year)	Journal or Conference	Field Setting(s)	Research Design	Contribution
Koenig (2012) tinyurl.com/cck69qa	*M@n@gement*	n.a.	Review and analysis of business ecosystem definitions and designs by different scholars	Contrasts and compares different definitions by Moore. Proposes a typology of four different categories of business ecosystems, associated control or resources, and degree of participation among the members of each ecosystem category: supply systems, platform, communities of destiny, and expanding communities.
Moore (1993) tinyurl.com/bnbulcj	*Harvard Business Review*	Cross industry, personal computer hardware, operating systems, software, automobile industry, retail industry, and pharmaceuticals	Proposition for the four evolutionary stages of a business ecosystem	Identifies the four evolutionary stages of a business ecosystem: birth, expansion, leadership, and self-renewal. For each stage, identifies the cooperative and competitive challenges in the ecosystem.
Purdy et al. (2012) tinyurl.com/bs9n5h2	*Strategy & Leadership*	n.a.	Proposition of three designs or categories of business ecosystems by examples of companies to include: Amazon, Athenahealth, Yipit, 1BOG, Polyvore, SOI, Napkin Labs, and GrowVC	Proposes a typology of three different categories of business ecosystems to include harbor and fleet (platform), demand forum (supply systems), and multivalent sourcing (expanding communities).

Koenig (2012; tinyurl.com/cck69qa) identifies four categories of business ecosystem: i) platforms, ii) supply systems, iii) expanding communities, and iv) communities of destiny. Platforms have reciprocal interdependence and centralized control of key resources by the firm providing the key resources. Supply systems have pooled interdependence and centralized control of key resources. An example of a supply system is Nike (nike.com), which controls a system of resources. Expanding communities have reciprocal interdependence and decentralized control of key resources. This type of ecosystem is usually a knowledge-exchange community, such as an open source community. Finally, communities of destiny have pooled interdependence and decentralized control of key resources. The Sematech consortium (sematech.org) in the semi-conductor industry is an example of a community of destiny. Risks associated with each of these categories of business ecosystem vary, but are directly related to control (centralized or decentralized) and interdependence (pooled or reciprocal).

The six categories of business ecosystem identified from the literature are shown in Table 3. The main characteristics, attributes, activities, and examples are summarized for each category.

In summary, the risks associated with the category of business ecosystem include:

1. General risks:
   - complexity of relationship management (between actors and the keystone)
   - control (centralized or decentralized)
   - co-opetition (simultaneous cooperation and competition)

2. Platform risks:
   - potential loss of intellectual property rights
   - centralized control of key resources
   - actor/keystone reciprocal interdependence

3. Expanding Communities risks:
   - actor/keystone reciprocal interdependence

4. Communities of Destiny risks:
   - actor/keystone pooled interdependence

5. Multivalent and Demand Forum risks:
   - replication of the company's business model by competitors

Table 2. Summary of literature on risks associated with participating in business ecosystems

Author (Year)	Journal or Conference	Field Setting(s)	Research Design	Contribution
Adner (2006) tinyurl.com/bpj4syf	Harvard Business Review	n.a.	Proposition for delays driven by an ecosystem	Identifies three types of ecosystem risks: initiative, interdependence, and integration.
Adner & Kapoor (2009) tinyurl.com/ch8bors	Strategic Management Journal	Global semiconductor lithography equipment industry from 1962–2005	Hypotheses tested in the context of the industry using both primary and secondary data sources	Identifies challenges associated with upstream component suppliers and downstream complementors. Upstream challenges may prevent a firm's ability to offer or delay offering the product while downstream challenges may prevent or delay a customer from using the product.
Bengtson & Kock (1999) tinyurl.com/cpyea3u	Journal of Business & Industrial Marketing	Rack and pinion industry in four Swedish manufacturing companies that make construction lifting equipment or mast-climbing platforms	Case-study approach from 1990–1993 interviewing managers in the industry	Identifies challenges associated with horizontal relationships, including: coexistence, cooperation, competition, and co-opetition. The choice of the relationship depends upon the firm's strengths or weaknesses.
Calcei & M'Chirgui (2012) tinyurl.com/cyna3th	Innovation: Management, Policy & Practice	Video storage industry in Japan, USA, and Europe	Examined coalition dynamics through the evolution of three standards in video storage formats based upon secondary data obtained from Internet sites	Identifies items key to the success of establishing a standard in an ecosystem by creating an alliance. Success depends upon alliance size, rivals in the alliance, and major players.
Daidj & Jung (2011) tinyurl.com/bqawuwz	Journal of Media Business Studies	Media industry and video game sector	Theoretical determinants of co-opetition are presented; structural characteristics of the media industry are analyzed with the strategies	The value of co-opetition when positions change and resources evolve.
Isckia (2009) tinyurl.com/d659zcx	Canadian Journal of Administrative Sciences	Amazon's ecosystem	Explanation of Amazon's platform role and the development of the ecosystem	Describes the evolution of the Amazon ecosystem from a cyber bookstore, to a cyber market, to an application service provider over an 11-year period. Identifies three functional groups to include: keystone, dominators, and niche players in a platform ecosystem with associated risks.
Ning et al. (2009) tinyurl.com/cydu39r	China-USA Business Review	n.a.	Proposition for three strategies for a business ecosystem's development from the perspective of an enterprise	Proposes three types of strategy: core (control of ecosystem), domination (grabbing value), and slit (resource focus). Also proposes three ecosystem development strategies: comply (stable ecosystem environment), fast follow (uncertain environment), and survival and multiply (fast ecosystem environment).
Pierce (2008) tinyurl.com/cxjgjxt	Strategic Management Journal	Automotive leasing industry from 1997–2002	Examined how manufacturer product design and niche-market entry drive complementor's losses and exits based upon a proprietary database of 200,000 car leases	Identifies the dependency of complementors on core firms and the risks associated to the complementor when the core firm changes pricing, product design, product redesign, durability, subsidization, marketing, diversification, and regulatory influence.
Vaz et al. (2013) tinyurl.com/brxlkpn	Revista de Administracao Contemporanea	Video game console industry	Literature review of the video game ecosystem and previous visualization and analysis studies are reviewed	Identifies the risks associated with superstars, the disproportionate capture of value from the ecosystem.

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Table 3. Prominent attributes and examples of business-ecosystem categories*

Category	Characteristics	Main Actor	Access	Activities	Examples
Platforms / Harbor and Fleet	A main actor that operates a platform and infrastructure. Shares a key asset, or resource, or services to other smaller actors in the business ecosystem. The main actor specifies the rules that must be followed for use of the platform.	Yes	General	Main actor shares for mutual economic benefits. Other actors use the key resource or services in developing their own products or services.	Amazon, Athenahealth, IBM 360, Video game consoles, Apple's iPod
Demand Forum	A main actor that aggregates other actors together in the business ecosystem. Brings together buyers and sellers.	Yes	General	Main actor aggregates buyers and sellers for increased range of goods and services and discounts prices.	Yipit, 1BOG, Polyvore
Multivalent	A main actor that supplies resources such as talent, innovation, funding, and raw materials for production.	Yes	General	Main actor provides information and resources to other actors in the form of crowdsourcing.	Prime Advantage, Napkin Labs, GrowVC, InnoCentive
Supply Systems	A main actor is lacking in certain key resources. The key resources are obtained from a select group of other actors that provide the key resources to the main actor. The main actor controls the other actors.	Yes	Privileged	Other actors supplying key resources or services to a main actor in product development.	Nike
Expanding Communities	A large number of actors that are grouped around a central non-proprietary resource for the benefit of all actors.	No	Membership	Software development of the non-proprietary resource.	Knowledge-intensive communities, open source communities, Nikonians
Communities of Destiny	No key assets. Actors organize through solidarity around a central issue to their existence in an industry.	No	Membership	All actors cooperate to resolve central issues to their mutual benefit in industry.	Sematech

*Based on descriptions in Koenig (2012; tinyurl.com/cck69qa) and Purdy et al. (2012; tinyurl.com/bs9n5h2)

Moore (1993; tinyurl.com/cygzy60) identifies risks relating to the four evolutionary stages of a business ecosystem: birth, expansion, leadership, and self-renewal. These risks are contrasted between the cooperative and competitive aspects for each stage and include:

1. Working with customers or protecting ideas at birth

2. Bringing new ideas to market, working collaboratively, or defeating similar ideas during expansion

3. Providing a compelling vision for the future or maintaining status quo during the leadership phase

4. Working with innovators or maintaining high barriers during the self-renewal phase

Risks associated with participating in the business ecosystem

As summarized in Table 2, there are nine articles that relate to after-entry risks associated with participating in business ecosystems. Adner (2006; tinyurl.com/bpj4syf) identifies delay-risks relating to the type of business activity, interdependence (joint probability of succeeding on time) and integration (intermediaries between the company and the customer). These risks relate to delays in development or time to market and participation with other actors. Adner and Kapoor (2009; tinyurl.com/ch8bors) identify further delay-risks based upon the company's location in the ecosystem and its upstream relationships (component suppliers) and downstream relationships (complementors). The risk of delay may be high or low depending upon the magnitude of the risk. Bengtsson and Kock (1999; tinyurl.com/cpyea3u) identify risks with horizontal relationships as they relate to co-existence, cooperation, competition, and co-opetition, essentially, the impact of weak relationships and the change in the relationship. Calcei and M'Chirgui (2012; tinyurl.com/cyna3th) identify the risk associated with technology-standard wars and the risk of building the best alliance with competitors and all of the key actors to ensure success. Daidj and Jung (2011; tinyurl.com/bqawuwz) identify the risks associated with rapid change and convergence in an industry and the need to reorganize with the best alliances as the company transitions into co-opetition relationships. Isckia (2009; tinyurl.com/c659zcx) identifies the risks encountered when participating with a keystone that operates at both ends of the supply chain. There is risk that a transformation may change the nature of the relationships. There is also risk that a keystone may attract a new actor that presents a threat to the company. Pierce (2008; tinyurl.com/cxjgjxt) identifies risks relating to the participation between a core actor and niche player. Changes in a core actor’s products and service may force a niche player to exit the business ecosystem. Vaz and colleagues (2012; tinyurl.com/brxlkpn) identify risks when one actor creates a "superstar" product or service that takes a disproportional amount of value in the business ecosystem. Finally, Ning and colleagues (2009; tinyurl.com/cydu39r) identify risks associated with participating with a dominator that takes full advantage of resources and value.

In summary, the risks associated with participating in a business ecosystem relates to four key areas:

1. General risks:
   - horizontal (co-existence, cooperation, competition, and co-opetition)
   - nature of the relationships
   - establish the best alliances
   - relationship between core actors and niche players
   - changes in core actors' products and services forcing a niche player exit
   - one actor creates a superstar product or service causing an imbalance in the business ecosystem
   - delays relating to the initiative, interdependence, and integration
   - dominating actors causing an imbalance in the business ecosystem

2. Keystone risks:
   - operating at both ends of the supply chain
   - threats from new actors attracted by the keystone

3. Risks from location in the value chain:
   - upstream relationships (component suppliers)
   - downstream relationships (complementors)

4. Standards risks:
   - wars
   - establishing the best coalition with actors
   - rapid change
   - convergence in an industry

Abstracting the Problem

An abstraction removes dependencies on the original context, in this case a business ecosystem that might limit or narrow the ability to identify potential solutions to the problem. Business ecosystems are a dynamic and constantly changing environment with associated risks that can make it difficult to grow value or, conversely, that can destroy value. This type of environment can be abstracted into a general framework of a dynamic, constantly changing environment with significant risks and potential value.

As an example of how this abstraction relates to other dynamic and constantly changing environments with risks, consider aviation. Pilots do not simply get into the cockpit and start flying the aircraft. Rather, a pilot knows in advance what type or category of aircraft they will be flying, and they will conduct a systematic pre-flight inspection of the aircraft. The type of inspection varies depending on the type of aircraft and the typical risks associated with it. Next, they use a checklist and conduct a systematic pre-flight inspection to ensure the aircraft is ready for flight, and this procedure varies based upon the category and type of aircraft. Once in the air, the pilot manages the cockpit resources, which includes threat management during all stages of the flight, and they proactively take any necessary corrective actions to deal with the risks. Despite significant risks associated with aviation, pilots are able to maximize the likelihood of a successful flight through their knowledge of these risks, the pre-flight inspections they make, and their real-time actions during the flight to monitor and manage potential threats.

Pilots receive training before earning their pilot's license, and they are very familiar with the category of aircraft they fly. Although entrepreneurs do not need an "ecosystem license" to participate in a business ecosys-

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tem, the abstraction described here illustrates parallel preparations that entrepreneurs should take before entering a business ecosystem and actions they should take while they interact within it. Entrepreneurs should identify the category of business ecosystems and associated risks prior to entering a business ecosystem. As shown in Figure 1, entrepreneurs need to conduct pre-entry inspections from different viewpoints to ensure risks are known and manageable prior to entry. Table 4 is a business ecosystem pre-entry checklist, which identifies risks with six categories of business ecosystem. This checklist is a synthesis of the potential risks across the six categories of business ecosystems. The pre-entry inspection should also identify the evolutionary stage of the ecosystem and associated risks. For example, upon conducting a pre-entry inspection the entrepreneur may discover a potential risk for loss of intellectual property rights for a platform business ecosystem they are looking to enter. One option to mitigate this potential risk is protecting the company's intellectual property *before* entering the business ecosystem.

Upon entering the business ecosystem, entrepreneurs need to constantly monitor and manage threats through real-time resource management when participating in the business ecosystem. For example, after entering the business ecosystem, an entrepreneur may notice that the keystone is attracting a new actor that may present a competitive threat to their business. One option is to embrace this new actor and determine how to cooperate and compete to simultaneously share value and revenues. This option is available because the entrepreneur identified the potential risk in advance and kept a watchful eye on that risk.

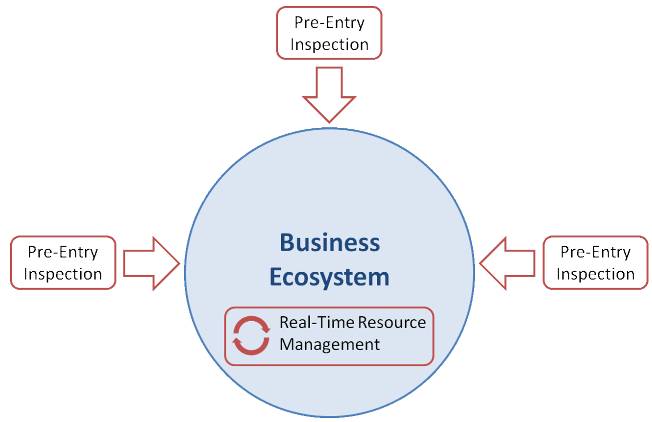

Figure 1. Risk management in a business ecosystem

Table 4. Risk-identification checklist for pre-entry inspection

Risks	Category of Business Ecosystem: Supply Systems	Demand Forum	Platform	Expanding Communities	Communities of Destiny	Multivalent	Risk Potential
Complexity of relationship management (actors and keystones)	✓	✓	✓	✓	✓	✓	**Always**
Control (centralized or decentralized)	✓	—	✓	✓	✓	✓	**Depends**
Co-opetition (simultaneous cooperation and competition)	✓	✓	✓	✓	✓	✓	**Always**
Potential loss of intellectual property rights	—	—	✓	—	—	—	**Depends**
Centralized control of key resources	—	—	✓	—	—	—	**Depends**
Actor/keystone reciprocal interdependence	—	—	✓	✓	—	—	**Depends**
Actor/keystone pooled interdependence	✓	✓	—	—	✓	—	**Depends**
Replication of business model	—	—	—	—	—	✓	**Depends**

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Recommendations for Entrepreneurs

From a close reading of the published research relating to the risks associated with different categories of business ecosystems and actor participation within them, an abstraction of the problem was developed to solve the problem. The abstraction led to the environment of aviation, where risk-management techniques are commonly used to deal with ongoing risks. Then, these known risk-management techniques from aviation are brought back to the business-ecosystem context in the form of recommendations relating to the specific types of risks identified in the literature. In this section, five recommendations are presented for entrepreneurs seeking to enter and participate in a business ecosystem.

1. Identify the category of business ecosystem before entering.
An entrepreneur should identify the category of business ecosystem before entering into it, because the corresponding potential risks are different in each category. For example, consider an entrepreneur who is interested in joining a business ecosystem. The entrepreneur has identified a main actor with key resources that may be shared under certain rules, and the entrepreneur is interested in using these key resources to develop a product. Table 3 will assist the entrepreneur with category identification based upon the prominent attributes of different business-ecosystem categories and associated examples. In this example, the entrepreneur has identified a category of business ecosystem known as a platform.

2. Conduct a systematic pre-entry inspection of the business ecosystem before entering.
After identifying the category of business ecosystem, a pre-entry inspection provides an opportunity to identify and understand potential risks associated with the category. The checklist in Table 4 will assist the entrepreneur with the inspection and identification of potential risks. For platform business ecosystems, an entrepreneur should check and secure intellectual property (Koenig, 2012; tinyurl.com/cck69qa) before entering the business ecosystem to avoid loss of rights, especially if a loss of these rights impacts the company's value and ability to grow value. The entrepreneur should think about centralized or decentralized control and the amount of independence they require or will accept, and they should check the state of the business system evolution (Moore, 1993; tinyurl.com/cygzy6o) to identify evolution, or a point-in-time-based risk.

3. Practice real-time resource management after entering the business ecosystem.
After entry into the business ecosystem, an entrepreneur should understand their company's position and role in the business ecosystem and conduct resource management in real time each day. Business ecosystems evolve and change and it is important to stay ahead of the evolution to ensure you grow value. For example, entrepreneurs should pay attention to the general risks identified in this article. They should watch keystones that may attract a competitive actor (Isckia, 2009; tinyurl.com/d659zcx), who may present a threat and either destroy or reduce the company's value. They should monitor their company's position in the value chain and look for rapid changes or convergence in the industry that may affect standards.

4. Pay attention to horizontal relationships, because risks are different between actors.
Horizontal relationships are key to a company's ability to grow value in a business ecosystem. An entrepreneur should check their company's dependency on component suppliers and intermediaries (Adner, 2006; tinyurl.com/cqesxlq), its position or location in the ecosystem (Adner and Kapoor, 2009; tinyurl.com/ch8bors), and the type of business relationship, co-existence, cooperation, competition and co-opetition (Bengtsson and Kock, 1999; tinyurl.com/cpyea3u). All actors in the business relationship have different risks, which can change and may inhibit the company's ability to grow value.

5. Pay attention to coalitions, because they can add value or destroy value.
Depending upon the situation, coalitions can be essential to a company's ability to grow value in a business ecosystem. Coalitions and horizontal relationships can be critical for standards (Calcei and M'Chirgui, 2012; tinyurl.com/bpnqnjw), and they can help when reorganizing into co-opetition relationships (Daidj and June, 2011; tinyurl.com/bqawuwz).

Conclusion

Entrepreneurs, managers, and executives should embrace business ecosystems. Entrepreneurs should consider business ecosystems for the purposes of starting up a company and growing value from day one. A systematic pre-entry inspection can identify initial business-ecosystem risks. Real-time resource management can identify participation based risks on a daily basis for corrective action. Early and ongoing identification of business-ecosystem risks are essential for to a company's success and its ability to grow value.

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This article reviewed the published research on business ecosystems as it relates to risks, presented the content and contribution of that research in a series of tables organized by business ecosystem categories and by business ecosystem risks, abstracted a solution to the problem of risks for entry and participation, and proposed five recommendations for entrepreneurs seeking to enter and participate in business ecosystems.

Business ecosystem risks may be grouped and associated by business ecosystem category. Risks may also be grouped and associated with participating in the business ecosystem. Entrepreneurs should pay close attention to their position in the value chain and their coalitions, because the actors are very important to success in a business ecosystem.

There are three interesting opportunities for further research: i) to further define categories of business ecosystems and their associated risks; ii) to further identify and create a topology of business-ecosystem interaction and participation risks; and iii) to identify effective strategies to monitor and mitigate the risks associated with business ecosystems.

About the Author

Derek Smith is the founder and principal of Magneto Innovention Management, an intellectual property consulting firm that assists entrepreneurs and small businesses to navigate and grow their international patent portfolios. He has over 20 years of experience working as an intellectual property management consultant and patent agent for IBM Canada, Bell Canada and, most recently, Husky Injection Molding Systems where he was Director, Global Intellectual Property. Prior to entering the field of intellectual property, he was an advisory engineer at IBM Canada where he was involved in a variety of leading-edge software development projects. Derek is currently a graduate student in the Technology Innovation Management (TIM) program at Carleton University in Ottawa, Canada. He also holds a BEng degree in Systems and Computer Engineering from Carleton University and is a registered patent agent in both Canada and the United States.

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TIM Lecture Series

Enhancing Competitive Position Through Innovation Beyond R&D

Sorin Cohn

> *Innovation is a renewable national and corporate resource to be developed, harvested, used, and commercialized for economic and social benefit.*
>
> Dr. Sorin Cohn
> President, *BD Cohn*sulting Inc.

Overview

The third TIM lecture of 2013 was presented by Dr. Sorin Cohn, President, *BD Cohn*sulting Inc. Drawing upon data from recent studies on innovation in Canadian companies, Dr. Cohn described the current state of innovation-management practices in Canada and brought forward specific recommendations to help enhance the competitive effectiveness of Canadian firms in the global marketplace. The event was held at Carleton University in Ottawa, Canada, on April 18th, 2013.

The TIM Lecture Series is hosted by the Technology Innovation Management program (carleton.ca/tim) at Carleton University. The lectures provide a forum to promote the transfer of knowledge from university research to technology company executives and entrepreneurs as well as research and development personnel. Readers are encouraged to share related insights or provide feedback on the presentation or the TIM Lecture Series, including recommendations of future speakers.

Summary

In light of Canada's poor performance in global "report cards" on innovation, Dr. Cohn argued that there is a need to "innovate innovation". The first part of the lecture focused on reviewing the processes, perspectives, theoretical models, and frameworks used to study and manage innovation. This review provided a backdrop for understanding innovation, which Dr. Cohn defined as:

> *"The process of creating value and differentiation through new or improved products or services, or new ways of pursuing the business goals and its operations, both internally to the organization and externally, within its entire environment (market)."*

Thus, the focus of the lecture was on "managing innovation beyond R&D". In particular, Dr. Cohn emphasized the need to develop a culture that supports innovation, which can have a greater impact on results than additional spending on traditional R&D.

A second important area of emphasis was on metrics to measure and manage innovation, which help a company:

- establish strategic direction and select the right innovation projects
- achieve strategic alignment
- monitor progress and guide corrective action
- optimize the allocation of resources and rewards for effectiveness and efficiency

Innovation issues in Canadian industry
In the second part of the lecture, Dr. Cohn focused on innovation in Canadian industry. A key message was

that, despite diverse investments in innovation and R&D, Canadian companies were not realizing great performance benefits from this investment. Although Canadian industry has traditionally received a lot of support, namely funding, to improve its foundation in science and technology, this is not the area of greatest need for Canadian companies. Rather than suffering from a "science and technology gap", Canadian industry is suffering from a "business/commerce gap", which results in a non-competitive position for Canadian companies. To close this gap, Canadian industry requires a focus on improving the business culture, customer focus, marketing and sales skills, global connectivity, and commercialization capability of Canadian companies.

According to Dr. Cohn, the following obstacles must be overcome to improve the competitive position of Canadian companies:

- a lack of will and competitive drive
- inadequate business and commerce skills
- insufficient innovation funding (i.e., not just R&D)
- a weak culture of collaboration
- ineffective management of innovation

Many companies expend great effort ensuring that their products are ready for the market, but Dr. Cohn asks, "Okay, the product is ready, but is the company ready for commercialization?" Success requires both product readiness and corporate-commercialization readiness. Moreover, commercialization should not be thought of as something that follows product development. Due to long timescales of commercialization, these activities should be undertaken early, in step with product development. Currently, Canadian companies are taking too long to commercialize, and they are taking too long perfecting their products.

Dr. Cohn also emphasized:

- the value of professional help from those with direct and local knowledge of your key markets: "You need to be *there*; think globally and act locally."
- the importance of collaboration for small and medium-sized enterprises, and the insufficient use of lead customers and anchor companies in Canada
- the inadequate levels of outside funding available for commercialization

Finally, Dr. Cohn highlighted that, although Canadian companies invest a lot of money in innovation, they do not spend a lot of time managing it. Furthermore, "the companies that spend a lot of time on innovation – but not on managing innovation – do worse than those that don't invest in innovation! And those that do both, do *very* well." In particular, Canadian companies need to measure the performance of their innovations using relevant metrics.

Innovating innovation management

In the final part of the lecture, Dr. Cohn shared "recipes" for managing business innovation:

1. Review vision and reality: The first ingredient for managing business innovation is for the company to review its vision: "Who are we? What do we want to become?" The company should also assess its competitive position along multiple dimensions to see whether the company's competitive position is aligned to its vision.

2. Nourish a culture of innovation: Although culture is difficult to measure and begins with leadership, a company-wide culture of innovation is essential. Innovation is about change and ambiguity about the future, which means that it is often thought to be "risky". However, the company leaders should understand that "not innovating" is the largest risk of all.

3. Adopt appropriate strategy and key targets: The company needs to understand why it is innovating, where it should innovate, what specifically it should innovate, and when the results are needed.

4. Select metrics and process: The company needs to select appropriate metrics and apply them within a consistent framework. It is not enough to just to measure, you need to understand the need to measure and focus on measuring the strategic areas of innovation, and then be prepared to react, learn, and adjust based on the resulting data.

5. Manage the innovation process: Taking the ingredients above, the management team must organize projects for its innovation-management activities, not as a one-off exercise, but as a continuous innovation process.

Finally, Dr. Cohn provided several recommendations to industry first and foremost, as well as to provincial governments and the federal government with its agencies supporting the innovation ecosystem.

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Recommendations

A. Industry needs to focus more intensely on competitiveness and global market penetration:

a. Align business plan and operational implementation with mission and culture.

b. Target marketing and sales in advance and be prepared for intensely effective commercialization.

c. Collaborate to conquer: anchor companies, local market partners for support.

d. Go for “smart money”: integrate financial and strategic support.

B. Provincial governments need to focus on enhancing the level of business education and the development of strong leadership and competitive skills, as well as creating a supportive provincial environment for risk capital and the commercialization of innovations developed in the province.

C. The Federal Government needs to rebalance its innovation focus from R&D to economic values and an environment for global competitiveness:

a. Provide coordinated programs and a comprehensive drive for a culture of commercialization success.

b. Develop flexible organizational structures and programs capable of being evaluated and adjusted as the reality of global markets requires.

c. Enhance accountability with measures for true industry/economy values.

d. Ensure the competitiveness of Canadian industry through effective commercialization support:

i. Save money from the Scientific Research and Experimental Development Tax Incentive Program (SR&ED; tinyurl.com/bxzvg2h) by eliminating waste; apply these savings to the creation of a balanced portfolio of programs aimed at enhancing competitiveness of Canadian industry.

ii. Consider tax-based incentives for "innovation in commercialization" and "effective collaboration" for true business success.

iii. Revitalize the Canadian venture capital industry.

iv. Provide direct commercialization-innovation support for small and medium-sized enterprises through a dedicated "commercialization preparedness assistance program" similar to the Industrial Research Assistance Program (IRAP; tinyurl.com/bmjx7gg).

v. Enhance IRAP for more consistent and effective support.

vi. Expand the Canadian Innovation Commercialization Program (CICP; tinyurl.com/af8sslh) for "innovation purchases" from small and medium-sized enterprises and accountable lead-customer nurturing.

vii. Support Canadian intellectual-property protection via SR&ED credits and IRAP support.

viii. Promote anchor-company relationships and clusters, possibly via SR&ED credits to anchor companies.

e. Link a percentage of academic research to industry via lead-customer commitments.

Key messages

The key messages from the presentation were:

1. Innovation is a means to an end, which is value and competitive success

2. An adequate innovation strategy based on a reality-anchored vision is important.

3. Culture and entrepreneurship matter a lot.

4. Innovation management is becoming a "science".

5. Using the right innovation-management technology (i.e., methodology, tools, and metrics) is critical.

6. We operate in a complex innovation *ecosystem.*

7. It is up to all of us – industry, academia, governments, etc. – to make it better.

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Lessons learned

In the discussions that followed each portion of the presentation, audience members shared the lessons they learned from the presentation and injected their own knowledge and experience into the conversation.

The audience also identified the following key takeaways from the presentation:

1. Innovation is paramount for competitive survival.

2. Doing more R&D does not necessarily result in more innovation.

3. Startups spend a lot of time and money conducting additional R&D, rather than devoting these resources to commercialization. This tendency should be reversed.

4. Commercialization planning and activities must start at the same time as innovation and product development; many companies start commercializing too late.

5. Canadian companies are good at producing high-quality products and services, but they are not good at commercializing them.

6. Companies should not wait until a product is perfect; they should quickly get their products into the market and then quickly learn from how the products are received.

7. We should recognize the importance of building a *culture* of innovation, both within companies and as a nation.

8. Our innovation culture should emphasize collaboration. Everyone needs to be involved, at all levels and both inside and outside of companies.

9. Many companies are not managing their innovation activities, to their detriment.

10. Many companies are not adequately measuring what they are doing in terms of innovation activities and outcomes.

11. When companies are self-assessing their innovation activities, they should involve every level in the company; the view on the front lines may not be the same as the view in the executive offices.

12. Investors understand the importance of metrics better than many companies; investors can help companies develop and apply appropriate innovation metrics.

13. There are many opportunities for companies to develop innovation-management software for companies.

14. Academic research can produce actionable recommendations for managing innovation.

15. Too many companies think that financing will solve all their problems.

16. In general, Canadian companies have a very weak customer focus.

17. Canadian companies need to devote greater effort to sales and marketing.

18. Local startup communities can benefit from large, global anchor companies.

19. Canadian companies focus too much on selling within their own province. Even a province-to-province paradigm is insufficient; Canadian companies need to "go global" or they may go out of business.

20. To go global, companies must develop partnerships, which can include local partners; companies should seek complementary partners that have global capabilities.

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This report was written by Chris McPhee.

About the Speaker

Sorin Cohn has 35 years of international business and technology experience, having been involved in most facets of innovation development: from idea to research and lab prototype, from technology to product, and then to market success on the global stage. He has developed new technologies, created R&D laboratories, started new product lines, and initiated and managed new business units. Sorin has several essential patents in web services, wireless, and digital signal processing, as well as over 70 publications and presentations. He has also been Adjunct Professor at the University of Ottawa. He is a Killam Scholar, and he holds a PhD in Electrical Engineering, an MSc in Physics, and an MEng in Engineering Physics. Sorin is President of *BD Cohn*sulting Inc. As well, he acts as Leader of Innovation Metrics at The Conference Board of Canada and as Chief Program Officer of i-CANADA. He is also Member of the Board of Startup Canada as well as the Board of the Centre for Energy Efficiency.

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Start by asking yourself:

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When writing your article, keep the following points in mind:

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