

Innovation Snapshot

Cloud Computing

Introduction

Despite the fact that experts have different opinions on the definition of cloud computing, Canadian business leaders agree that it is not “just hype” (only 7% think it is).¹ The paradigm of shared, scalable, on-demand computing resources is compelling to businesses as it promises to eliminate the administration of IT operations. Cloud computing offers a number of potential benefits including cost savings, scalability, increased productivity, as well as allowing organizations to focus on their core business.

Cloud computing is generally presented in three forms: Software as a Service (SaaS), delivering applications to end users through the web, such as SalesForce.com or Google Docs; Platform as a Service (PaaS), providing a development and computing platform under which companies can create and deploy their products, such as Windows Azure or Google App Engine; and Infrastructure

as a Service (IaaS), allowing users to rent virtual servers through the web in which to run their own applications, such as Amazon EC2. These types of services, additionally, can be deployed through: a public cloud, accessing shared resources through the internet; a private cloud, hosted by companies’ own servers internally; or a hybrid cloud, which combines the previous two.

Many experts see IT services in the future being a utility such as energy or water, where through an internet connection organizations demand as much as they require, providing increased agility and efficiency. Additionally, adopting cloud computing could help companies move resources away from IT administration and into research and development tasks to further innovation and progress.










SaaS	PaaS	IaaS
		
		
		

Table 1: Cloud computing providers by type

Canada

The Canadian cloud-computing market was estimated at around \$260 million dollars for 2010, and recent surveys suggest that as many as 85% of Canadian companies use some level of cloud solutions; however, Canada still lags behind the United States in terms of adoption. This relative lack of adoption creates a considerable growth opportunity for cloud service providers, with the market expected to grow at 32% annually in the next 5 years (compared to 19% in the United States).

In addition to established players such as CGI, HP and IBM (which recently announced its public IaaS Smart Business Compute Cloud service) and other early market entrants such as CentriLogic and RackForce, telecom providers including TELUS and Bell also offer IaaS solutions in Canada. Cloud-computing lowers barriers to entry into the IT market by allowing small enterprises to use servers in the cloud instead of buying their own, given

this, there are many SaaS providers in the country with a broad number of web-centric solutions ranging from accounting to collaboration tools. IDC expects SaaS and IaaS to reach \$1 billion in Canada by 2014.²

Given that privacy concerns is one of the top barriers to cloud adoption, Canada has a global competitive advantage when it comes to offering cloud services. Canada's Personal Information Protection and Electronic Documents Act (PIPEDA) ensures that businesses use data appropriately by protecting personal information, giving individuals the right of knowing how their information is collected, used or disclosed. Canadian Data privacy regulations (PIPEDA) give businesses and consumers much higher confidence than regulation in the United States (Patriot Act), allowing companies in the region to offer cloud services which better serve businesses' data privacy policies.



Figure 1: Data Centers Canada, a Toronto Region company, takes advantage of PIPEDA to promote their hosting and colocation services.

The Toronto Region

With over 13,000 companies, the Toronto Region is Canada's largest ICT hub. Given the growing interest in cloud computing as a promising and disrupting technology, and the entrepreneurial attitude that exists in the region, Toronto has managed to produce various successful companies in this area. Additionally, many large players which are active in cloud computing have offices in the region.

IBM (Markham)



IBM, one of the largest providers of cloud solutions in the world, maintains a very strong presence in the region. Its Toronto research lab is the largest software development facility in Canada, and it is IBM's third largest in

the world. In addition to development of their DB2 and WebSphere products among others, the facility is

also home to IBM's Centre for Advanced Studies (CAS) in Canada. The CAS fosters innovation through collaboration between IBM's technical leaders and academic researchers at post-secondary and government institutions, with one of their 'technology themes' being *Cloud Computing and Infrastructure*.³

The company has also recently opened the IBM Smart Business Compute Cloud Centre in the region, a \$42 million investment which can take advantage of the country's favourable policy framework and the region's talent to serve customers interested in moving IT applications to the cloud; the center is one of IBM's six delivery centers for their new Smart Business Cloud IaaS offering.⁴



Rypple (Toronto)

Founded in 2008 in Toronto, Rypple provides SaaS

which aims to boost productivity through increased collaboration and communication in the workplace. Performance reviews which are months apart are often the only source of feedback employees get – taking advantage of the web and the evolution of social media, Rypple started as a way to improve the work review process through an online tool which encourages anonymous and frequent feedback from colleagues.

Since their first beta release in November 2008, Rypple has evolved into an area they define as the “gamification” of the workplace, hoping to make work fun by allowing people to create and give virtual rewards, track goals, manage teamwork, and most importantly, communicate. Rypple has raised over \$15 million in funding and is used by many organizations including Mozilla, Cisco and Rackspace.

Platform Computing

Platform Computing (Markham)

Songnian Zhou’s computer science PhD thesis, “Dynamic

Load Sharing in Distributed Computing”, completed in 1987, was the basis for what would later become Platform Computing. Zhou’s research would lead him and a University of Toronto colleague to develop a solution to manage resources and workload in distributed computing systems, co-founding Platform Computing in 1992. Since then, the company has become a leader in resource management software for computing in clusters, grid and cloud architectures. Their strong heritage in grid computing served as the foundation for the company’s successful cloud computing offerings.

With over 500 employees and 15 offices around the world, Platform Computing’s customers include Hewlett Packard, Samsung, Sony, Motorola, Toyota and Ford. The company has also established strategic partnerships with IBM, Microsoft, Dell, and SAS among others.



Enomaly (Toronto)

Founded in 2004 in Toronto, Enomaly develops software

which allows hosting providers or telecommunication companies to efficiently build and offer their own Infrastructure-as-a-Service. Enomaly’s *Elastic Computing Platform* has been described as the first true IaaS platform, allowing companies to easily enter the cloud computing market. Enomaly has also created *SpotCloud*, an online global market for computing power which allows companies to take advantage of the cloud by selling excess computing capacity, while others can buy affordable computing according to their needs.

Enomaly was recently named one of the top 50 cloud innovators in the Structure 50 report,⁴ among well-known cloud players such as IBM and Amazon.

Did you know...

The term “cloud computing” was first defined in 1997 by Information Systems professor Ramnath Chellapa at the University of Texas. He described cloud computing as a “computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits.”⁵



CiRBA (Richmond Hill)

CiRBA, founded in 1999 in Richmond Hill, could be described as a cloud

enabler. Through their Data Center Intelligence software, CiRBA’s patented technology allows businesses to manage and analyze their virtualized and cloud computing environments. Their analytics software determines the optimal workload and resource allocation to maximize the efficiency of virtual and cloud infrastructure. In addition, CiRBA’s solutions also help companies efficiently migrate their IT services to the cloud. CiRBA’s partners include Cisco, IBM and Intel among others.

Other cloud computing firms from the Toronto Region include: Asigra, BoardSuite, ThinDesk, FreshBooks, Nulogy, Synaptop, PollStream and KineticD.

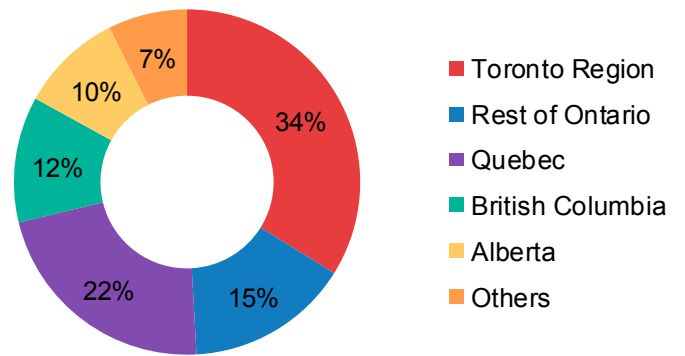
Talent and Labour Force

The Toronto Region possesses one of the most diverse and best educated new workforces in Canada. The region employs around a third of Canada's ICT labour force. Despite a highly educated workforce, the region's average salaries for information and communications technology (ICT) professionals are below that of comparable ICT clusters in North America.

Located in the region are two of the best schools for engineering and ICT-related studies in the world, the University of Toronto (UofT), ranked 14th, and the University of Waterloo (UW), ranked 39th.⁶ They attract some of the brightest students from Canada and around the world.

Figure 2: Regional Distribution of ICT Labour Force in Canada

411,065 people employed



Source: TRRA Analysis based on Statistics Canada

Table 2: Salary Comparison for North-American ICT Clusters

	San Francisco, CA	New York, NY	Boston, MA	Seattle, WA	Washington, DC	Toronto Region
Business Systems Analyst	\$96,625	\$92,697	\$90,271	\$85,575	\$85,949	\$82,442
Computer Hardware Engineer	\$104,338	\$98,982	\$98,092	\$92,043	\$93,588	\$91,922
Computer Programmer	\$89,881	\$86,197	\$83,867	\$79,762	\$79,943	\$75,541
Quality Assurance Analyst	\$98,642	\$94,648	\$92,189	\$87,343	\$87,751	\$86,900
Software Engineer	\$110,748	\$106,413	\$103,704	\$98,076	\$98,586	\$95,859

Source: ERI Salary Assessor

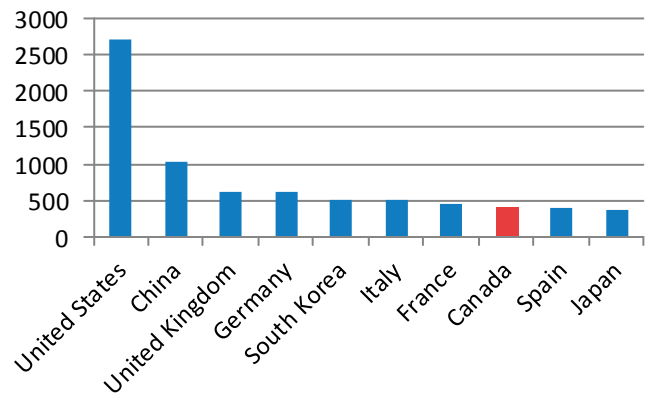
Research and Development

There are a wide range of technologies and research areas which are applicable and related to cloud computing including data structures, network resource allocation, workload balancing, and information security and cryptography among others. Canada and the Toronto Region are strong players in the cloud computing ecosystem as revealed by the number of patents and publications produced related to this growth area.

Publications

Globally, Canada ranks 8th in number of cloud related publications. The Toronto Region is the top publishing region in Canada. The University of Waterloo and the University of Toronto are among the top five publishers of cloud related articles.

Figure 3: Top countries by number of cloud related publications (2001 - 2010)



Source: TRRA Analysis based on ISI Web of Knowledge

Patents

Canada is the fourth country in the world for cloud computing related patents. Within Canada, the Toronto Region is the leading region in cloud computing patents. Six of the top ten patenting cities in the country are located in the region.

IBM is the top patenting company in Canada for cloud computing technologies. Other companies in the region which hold cloud related patents include Platform Computing and CiRBA.

Did you know...

A cool location like the Toronto Region could save large cloud computing data centers thousands of dollars in energy bills compared to warmer locations farther south in the United States.

Government Funding

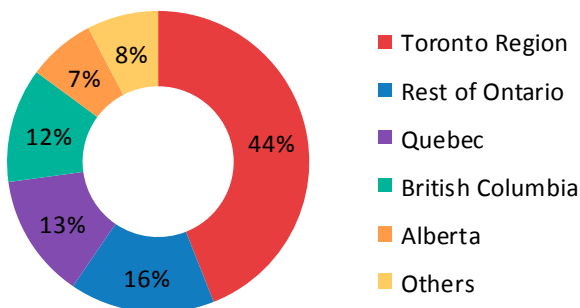
The Toronto Region receives more funding for cloud computing research than any other region in the country. From 2001 to 2010, the region received over \$3.5 million for 72 cloud related projects. This represents 44% of the total funding provided by NSERC and CFI for cloud projects in all of Canada (\$8.1 million).

The University of Toronto and the University of Waterloo were the top recipients of funding for cloud computing projects, 59 projects valued at over \$3 million were funded at these two institutions.

Researchers

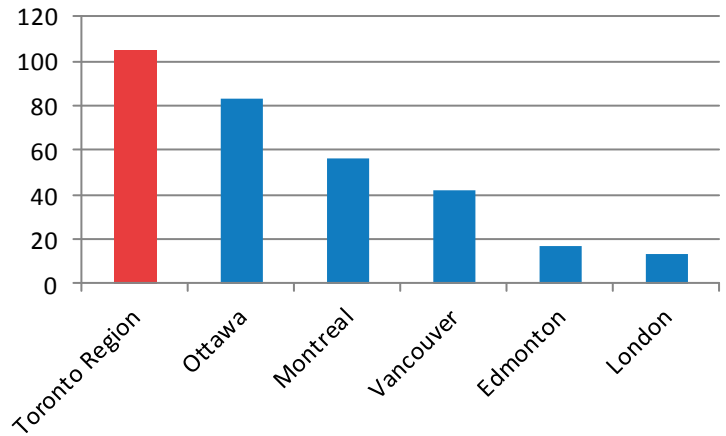
Figure 7: Regional Distribution of projects funded by NSERC and CFI (2001-2010)

Total funding: \$8,750,827



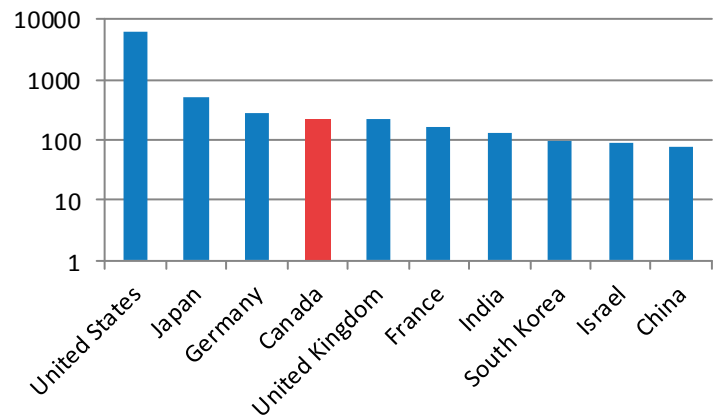
Source: TRRA Analysis based on NSERC and CFI

Figure 4: Top regions in Canada by number of cloud related publications (2001-2010)



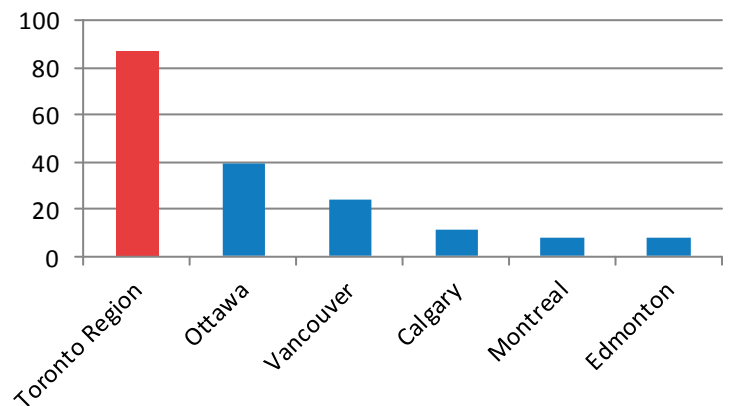
Source: TRRA Analysis based on ISI Web of Knowledge

Figure 5: Top countries by number of cloud related patents (2001-2010)



Source: Thomson Reuters
Note: Log-scale

Figure 6: Top regions in Canada by number of cloud related patents (2001-2010)



Source: Thomson Reuters

There are many researchers in the region working on cloud computing related problems. Common research topics include resource allocation, load balancing, optimization and virtualization. Although many of these problems are common across different computer science applications, we now highlight four researchers who have explicitly focused on cloud computing and who have received government funding from either NSERC or CFI.

**Raouf Boutaba, Professor
University of Waterloo**

Selected Research: Boutaba and his team proposed using market demand forecasting and dynamic resource allocation across spot markets (where each spot market uses different Virtual Machine (VM) types) to maximize revenue of cloud providers. The mechanism and algorithms proposed are shown to approximate an optimal solution to the problem of revenue maximization for cloud providers with different VM types.⁷



Has worked with: Bell, Nortel, Cisco, Alcatel.

**Marin Litoiu, Associate
Professor
York University**

Selected Research: Proposed an optimization architecture for the design of cloud management schemes. Through virtualization, a layered cloud structure which self-automates activities such as monitoring and analysis could address some of the challenges of optimization in cloud architectures. IBM has recognized professor Litoiu for his leadership in cloud computing research, and will collaborate with him and fund new projects throughout 2011.⁸



Has worked with: IBM, Amazon, CA Technologies.

**Eyal de Lara, Associate Professor
University of Toronto**

Selected Research: Developed a system for cloud computing which introduces Virtual Machine cloning as a first-class primitive, that is, a basic function type to be used as a building block for higher-order programming functions. By doing this, the process of VM cloning is made more efficient and flexible, allowing cloud environments to offer better scalability for high performance computing.⁹



Has worked with: Platform Computing, Google, Bell.

**Ashraf Ismail Aboulnaga,
Associate Professor
University of Waterloo**

Selected Research: Quantified the overhead costs of server virtualization for database systems through an experimental study. The study shows that although there exists a resource overhead for database systems, it is on average less than 10%. His research concludes that overhead costs are reasonable given the manageability benefits of virtualization: server consolidation, easier deployment and flexible provisioning.¹⁰



Has worked with: Google, IBM.

Conclusion

Cloud computing is only a nascent concept and there are many challenges that need to be addressed before the “computing as a utility” view can be achieved. Nearly seamless migration, stronger security and more robust privacy policies are necessary before a full transition of IT services onto the cloud takes place. Private clouds at large corporations and the use of SaaS in small and medium enterprises have so far had promising results. As scientists and engineers continue to improve the reliability, efficiency and security of cloud environments and the benefits of the technology become even more apparent, more businesses and organizations will choose to adopt cloud computing.

Thanks to a strong ICT research and business environment characterized by world class post-secondary institutions, innovative researchers, entrepreneurial talent, and continuous government support, the Toronto Region is well positioned to take advantage of this emerging trend.

References

1. CA Technologies Study on Cloud Computing (Leger Marketing, 2010)
2. IDC, Cloud Computing: The Next Form of Outsourcing, [web page] (2011) <<http://www.idc.com/getdoc.jsp?containerId=CA12SSC11>>, accessed 20 Jul. 2011.
3. IBM, ‘Canada CAS Research’, [web page] (2010) <<https://www-927.ibm.com/ibm/cas/canada/research/index.shtml>>, accessed 27 May. 2011.
4. GigaOM, The Structure 50, [web page] (2011) <<http://pro.gigaom.com/2011/05/the-structure-50-the-top-50-cloud-innovators>>, accessed 21 Jul, 2011.
5. Cloud Computing World, When Did Cloud Computing Develop?, [web page] (2010) <<http://www.cloudcomputingworld.org/cloud-computing/when-did-cloud-computing-develop.html>>, accessed 27 September. 2011.
6. US News and World Report, World’s Best Universities: Engineering and IT, [web page] (2010) <<http://www.usnews.com/education/worlds-best-universities-rankings/best-universities-engineering-and-it>>, accessed 24 May 2011.

7. Qi Zhang, Eren Gurses, Raouf Boutab, “Dynamic Resource Allocation for Spot Markets in Clouds” <http://www.usenix.org/event/hotice11/tech/full_papers/Zhang.pdf>
8. Marin Litoiu, Murray Woodside, Johnny Wong, “A Business Driven Cloud Optimization Architecture” <<http://www.yorku.ca/mlitoiu/papers/Cloud%20Optimization%20Architecture%20v5.pdf>>
9. SnowFlock: Swift VM Cloning for Cloud Computing <<http://sysweb.cs.toronto.edu/snowflock?>>
10. Umar Farooq Minhas, Jitendra Yadav, Ashraf Abounaga, Kenneth Salem, “Database Systems on Virtual Machines: How Much Do You Lose?” <<http://www.cs.uwaterloo.ca/~ashraf/pubs/smdb08overhead.pdf>>

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