The HPC4Health Network

Building an Ontario-wide platform for human health data

HPC4Health: High-Performance Data and Computing for Health Care

PUBLISHED BY HPC4HEALTH

WWW.HPC4HEALTH.CA

Executive Summary

The explosion of human health data can mean new advances in human health care — but only if the infrastructure, architecture, policies, and expertise are brought together in innovative ways to make effective, safe research use of the data. We have such an example of a collaborative center in Ontario, in HPC4Health.

An innovative and successful shared platform for health genomics data and analysis, the original incarnation of HPC4Health in 2014 was a small pilot project between SickKids and UHN; today, the collaboration counts amongst its employees six scientific and eight technical staff, works with four partner institutions, and provides 7,000 compute cores and over 2 petabytes of secure data storage.

Human Health Research in the Era of Genomics

Next-generation genomics and electronic medical records have become ubiquitous almost simultaneously, opening completely new windows onto the field of human health research.

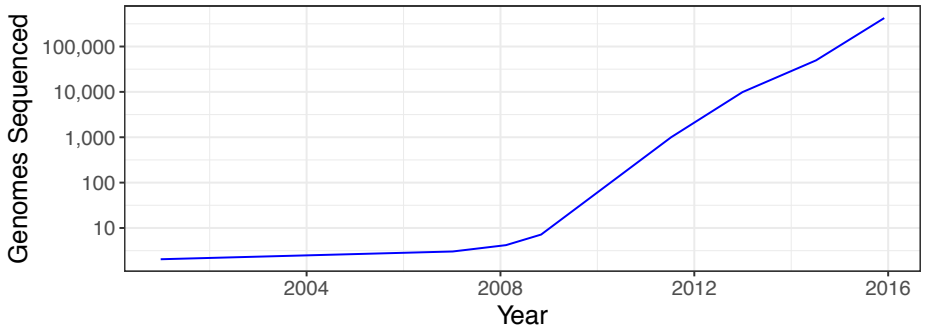


Figure 1: The cumulative number of human genomes sequenced over the past 15 years, data from [Stephens et al., 2015]. New technologies and data types have caused a inflection in the exponential rate of data growth which continues today.

In genomics, an exponentially-growing number of human genomes are being sequenced, making enormous amounts of evidence on the heredity of human disease states at previously inaccessible levels of detail (Fig 1). Data rates are only increasing as new devices become available, and new types of data are being generated; for instance, RNA sequencing allows us to go beyond simply sequencing "the" genome of an individual and instead measure the gene products being expressed in particular cells at particular times, giving us insight into not just predispositions but the precise disease state of cells over time.

Until now, the bulk of this genomic data has come from research projects — focused, generally short-term efforts to answer specific questions using genomic information. However, two changes in the practice of medicine are poised to radically increase the rate of genomic and human health data creation in Canada.

First, genomic medicine[1] is beginning to enter the standard of care, initially in the cases of hard-to-diagnose rare diseases or recurrent cancers, and starting to displace smaller and more limited genetic tests in other areas. The sheer scale of clinical medicine — in Canada, hospital spending alone is

[1] Genomic Medicine, as defined by the NIH's National Human Genome Research Institute: "An emerging medical discipline that involves using genomic information about an individual as part of their clinical care (*e.g.*, for diagnostic or therapeutic decision-making)"

nearly seventy times the research funding budget of the CIHR — means that as adoption increases, clinical genomic data creation will rapidly outpace that of research genomic data.

Second, information technology advances elsewhere in healthcare has led to the rapid adoption of Electronic Medical Record systems[2], describing a patient's condition, tests, and treatment in detail and at least partially in machine-readable form.

[2] Electronic Medical Records, or EMRs, are digital version of paper chapters in hospitals or doctors offices; Electronic Health Records, or EHRs, are more integrated systems combining information across practices and institutions. EMRs are mature and growing in adoption rapidly, while EHR systems are still some time from being common.

The rapid growth of genomic data volumes and the increasing depth and detail of clinical data present in EMRs offers enormous promise for human health research, with insights into both basic biology and to future treatments. The joint analyses of clinical and phenotypic health record data along with genomic information about the patient and their disease offers unprecented opportunity for researchers to connect genetic predisposition, treatments, and outcomes, allowing the development of national, truly precision, medicine practices.

But making use of this data in an era of rapid growth raises multiple challenges. On the physical infrastructure side, simply making available the storage resources to capture and archive the onrush of data is a daunting effort, along with providing the computational power to perform increasingly sophisticated analyses. Architecting, building, and maintaining these systems, particularly tuned to the needs of health research, requires a specialized approach.

Human infrastructure is also required. Making productive use of the data means ensuring that the expertise exists and is available to for interpretation, and that those experts are continuously kept up to date on the new types of data and new techniques for analysis. This requires funding, ongoing training, and opportunities for professional recognition and growth of the experts, whether they be bioinformaticians, computational biologists, or systems administrators.

Finally, the unique challenges of dealing with health data means that the duty of care to patients to zealously protect the security and their privacy is paramount; sophisticated and enforcable policies around data governance and consent are required, along with international best practices around security and monitoring.

The explosion of human health data can mean new advances in human health care — but only if the infrastructure, architecture, policies, and expertise are brought together in innovative ways to make effective, safe research use of the data. We have such an example of a collaborative center in Ontario, in HPC4Health.

HPC4Health — a Made-in-Ontario Approach

As early and major players in genomic research and medicine, in 2014 SickKids and the University Health Network (UHN) faced a problem — how to manage and make use of the influx of genomic and other health data they were already charged with storing and analyzing.

With a common challenge, and building on existing partnerships, the institutions formed a first-of-its-kind collaboration and in Ontario, combining forces and sharing resources to build HPC4Health[3]: a shared-services approach, building a cross-institution center of infrastructure and expertise for the analysis of human health and genomic data. This innovative partnership gathered much attention in the hospital, genomics, and research computing communities [Hospital News, 2014, Genome Web, 2014, Inside HPC, 2015, Telfer, 2016].

[3] http://www.hpc4health.ca

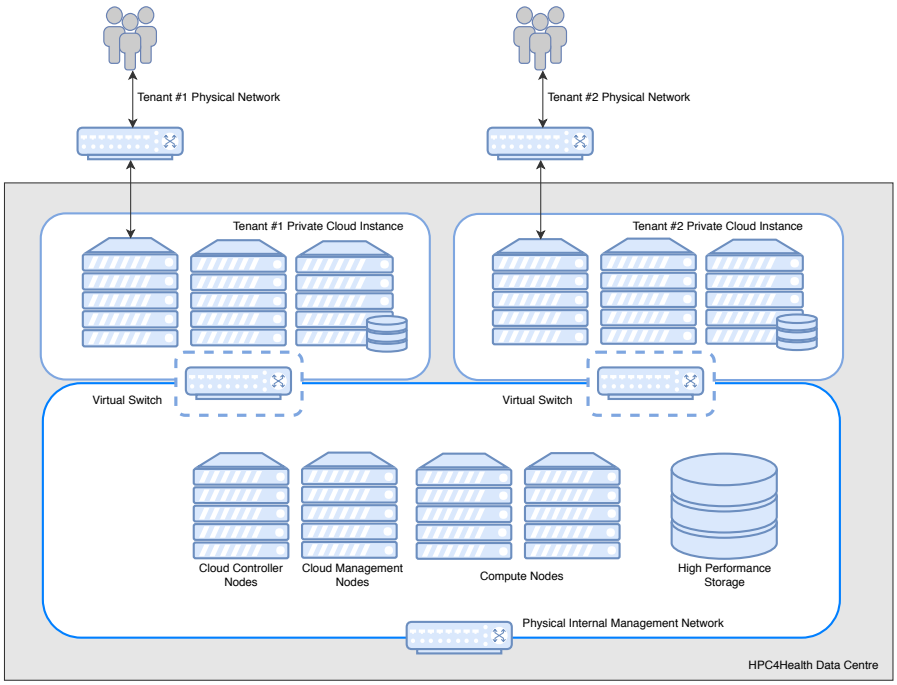


Figure 2: The HPC4Health Architecture. An on-premesis (at SickKids) private cloud is partitioned into tenant-controlled secure data environments for the institutions, with shared administrative resources managed by the HPC4Health administrators. Tenants can get technical support from the core technical staff, or scientific support from the growing team of genomics, machine learning, and health record experts.

HPC4Health's compute and storage infrastructure (Fig 2) consists of an elastic secure cloud — an arrangement that functions like an office building rented to multiple tentants. The "superintendant" maintains core shared facilities, but the "tenants" have complete control of their own office space. This is implemented through in an on-premises private OpenStack[4] cloud, partitioned securely into an administrative core and "tenant" environments.

[4] https://www.openstack.org

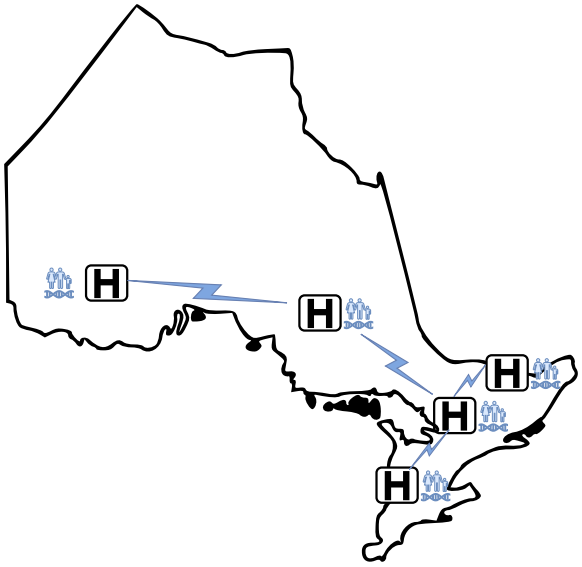
Crucially, HPC4Health is more than computational infrastructure; it is also experience and expertise. HPC4Health is governed by a sophisticated policy and data governance framework; it is governed by an executive committee and a science advisory panel; and is run by teams of technical and scientific personnel that every day make sure that health insight is successfully distilled from health data.

The original incarnation of HPC4Health in 2014 was a small pilot project between SickKids and UHN; today, the collaboration counts amongst its employees six scientific and eight technical staff, works with four partner institutions, and provides 7,000 compute cores and over 2 petabytes[5] of secure data storage.

[5] A petabyte is over a million gigabytes, and is enough to store over three years worth of 24/7 high-definition video or the raw data of nearly 7,500 whole genome sequencing experiments.

The H4H Network — Building on Strengths

Figure 3: The H4H Network



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