# Cloud computing for building effective information systems in sport

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# Research Methods and Professional Practice

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# November 2022

# Objectives

The objective for this literature review is to review the various uses and literature in the topic: Cloud computing for building effective information systems in sport. It takes a thematic structure, and its audience are the author’s peers, those who are considering developing cloud information systems in sport, or anyone that has a passing interest in the topic.

A literature review should not be a simple review of research already performed in the field, it should clearly show how the author constructed their knowledge and how it leads to further research (Lather, 1999).

Unless particularly relevant, this literature review has made every effort to include sources no older than six years, due to the rapidly changing landscape of the topic.

# The Current Landscape

Cloud technology is fast becoming the de-facto method of computing, and is popular due to the following advantageous characteristics:

* Elasticity: Services can be expanded or reduced on demand
* Reliability: Most cloud service providers (CSPs) guarantee an uptime of >=99.99% per year through service level agreements
* Scalability: Cloud computing allows scalability in terms of an application’s use in the field, due to its decoupling nature
* Cost: It is often cheaper for organisations to rent cloud services than to purchase hardware
* Security: CSPs often have their own in-built security, or the ability to add security features. Physical security concerns of on-premise data centres are also extinguished
* Ease of setup: Servers can be spun up within minutes
* Redundancy: Data stored in the cloud is usually duplicated or backed-up easily and securely
* Mobility: By moving data to the cloud, it enables it to be available anywhere in (or out of) the world
* Heterogeneity: Clouds are typically technology agnostic

In the sports industry, information technology tends to be under-funded as a whole. However, by moving to the cloud, IT personnel can concentrate on creating innovative services for their sports teams to run more efficiently, or improve fans’ experience (Woodin, 2022).

Amazon Web Services (AWS), currently the world’s largest CSP, discovered that their sports customers now value a more personalised experience. They found that teams and clubs prioritise winning as a business model, losing teams generally do not make good business models, and fans alike want to understand what makes a winning team (Amazon Web Services, 2022).

The two major scenarios where sport benefits from information systems in cloud computing are:

* Over The Top (OTT) media services
* Athletic performance and health analytics: Ranging from teams checking split times to athlete’s maximising recovery.

## Over The Top Media Services

OTT media is big business. Its market size was valued at more than $150 billion in 2021, and expected to reach $1241.6 billion by 2030 (Precedence Research, N.D.). OTT is a term used for any media provided to end users over the Internet, rather than traditional means, and delivers content to sports fans through live streaming or video on demand (VOD) services. Cloud computing facilitates resource heavy tasks, such as transcoding that OTT requires in spikes, thanks to its elasticity and scalability attributes. Content Delivery Networks (CDNs) are then typically leveraged to deliver the content to consumers with minimal latency. All of this in combination offers sports fans a more personalised experience, where they can watch what they want, when they want and where they want (Graham, 2020).

[Hutchins](https://journals.sagepub.com/doi/10.1177/0163443719857623#bibr22-0163443719857623) et al. (2019) describe media portals for delivering OTT as having six characteristics:

1. The privileging of liveness: The excitement of sporting competition reduces once the result is known
2. A mix of mass and niche services: Enabling lower level leagues of sports, disability sports, niche sports as well as the main events.
3. Changing rights territories: Allowing the possibility to access a wider range of countries thanks to the borderless nature of the Internet
4. Multiplying screens and spaces of consumption: Opening avenues for “datatainment”, including real-time statistics, infographics, betting markets etc.
5. Datafication or viewing and consumption habits: Allowing data scientists to develop systems tailored to develop larger viewing figures
6. Changing technical infrastructure and problems: Particular problems include buffering, which was not a problem with traditional broadcasting methods. In some cases, it can lead to a severe loss in business and refunds as in the case of Optus (ABC News, 2018).

With sufficient resources, OTT allows possibilities for viewers to watch more sport, in more places than is possible with traditional broadcasting means, and enable personalised experiences across multiple screens for multiple areas of interest ([Hutchins & Sanderson, 2017](Hutchins%20&%20Sanderson,%202017)).

Mahmood et al. (2019) successfully present a scalable framework using mobile cloud computing (MCC) to enhance the viewing experience for mobile device users inside the stadium. The system allows fans to gather stats in real time on players on the field using image recognition and then offsets the computational functions using artificial intelligence techniques in the cloud.

Brouwer (2002), however considers limitations of Internet of Things (IoT) and mobile use in stadiums and advocates the use of edge computing rather than using cloud computing due to the lack of Wi-Fi capability in most stadiums today.

## Athletic Performance

Cloud applications enable athletes in different geographical locations to compete against each other, and aids them in mastering their discipline by allowing them to leverage the cloud’s massive data processing power and perform data analytics. They also allow teams to extract the required data to buy greater success with minimal expenditure in a “moneyball” approach (Wassermann et al., 2005).

Yang & Ming (2021) present an athlete energy consumption monitoring system using a combination of SaaS, PaaS, and IaaS models in a Service Oriented Architecture (SOA) approach. It collates multiple types of data from multiple sources, analyses it, and feeds information back to participants who then alter their exercise intensity and times based on these data, therefore achieving superior results.

They also note that on-premise hardware servers can no longer satisfy such data storage and processing requirements that motion energy-consumption detection generates, and therefore is reliant on cloud technology, and again describe the benefits of on-demand elasticity cloud computing.

They concede however that typically, although acquiring more types of data makes it easier to comprehend energy consumption, it comes at a cost in terms of money and (system) power consumption.

They also acknowledge the high cost of using a private cloud over a public one, even though it may be possible to better secure the data within their own boundaries.

Ikram et al. (2015) and Mainetti et al. (2016) present new systems that leverage cloud and IoT sensor technologies to monitor statistics of players. Both doctors and coaches are then able to use the data to analyse health and performance, respectively. Ikram et al. (2015) note the importance of Quality of Service (QoS) and the security of data, and also compatibility with different software platforms and the inevitable need for stadiums to upgrade their infrastructure to enable such technology.

These cloud data processing techniques range from simple data retrieval to more sophisticated analytics techniques involving big data, or using technologies such as machine learning and neural networks.

Hong-jiang et al. (2013) take this one step further and propose a cloud-based sports training auxiliary system that continuously collects athlete’s kinetic, physiological, and biochemical real time data using various technologies, before transmitting them to the cloud. This then analyses the data to make decisions, augmented by a team of human professionals, before eventually providing trainers with a set of specialised sports training program.

Data does not have to come from the participant of the sport, however instead be gleaned from the sports equipment directly. This can be useful for analytics where a participant does not have the luxury of a personal coach. Pustišek et al. (2021) discuss some limitations to this including case specific weight restrictions and possible over violent use (golf ball) amongst various others. However, Gowda et al. (2018) show it was possible to embed sensors in their iBall example of a smart cricket ball.

Pustišek et al. (2021) refer to the use of these smart sports items with cloud computing technology as biofeedback technology, which can also help improve the rate of motor learning. However, again there are further limitations due to its intention of real time feedback through haptics and visual feedback, for example, which may render the smart aspect of the equipment unusable in certain real-time situations. They cite problems due to the limitations of short-range communication technologies and processing power capabilities in the sensor devices and smart phones, and latency over longer ranger communication links.

In this scenario, again fog or edge computing is cited as a solution, with the cloud still being used to provide long-term storage of aggregated data and bulk processing.

Hribernik et al. (2020) propose a standardised backend cloud application to accept various biomechanical data through application programming interfaces (APIs) from all hardware types that would normally require the use of incompatible proprietary information systems.

However, it is not only individuals who benefit from cloud computing. The USA cycling team leverage cloud analytics by uploading individual race data through a mobile app attached to their bicycles, live in-race analytics are then retrieved by other team members to gain small advantages. (Schlyer & Martinez, 2016)

The use of cloud computing to compute large amounts of data is not without its downsides, and Marr, B. (2017) highlight several catastrophic eventualities that could occur if athlete data at the top level be breached, including data theft and malware infection, which could ultimately cost them the advantage over the competition.

# Other Uses

Blobel & Lames (2020) describe how cloud-based club information system (CIS) should be adopted by sports clubs in general, using Liverpool football club as an example. Such systems can integrate data from many sources including training, medical, and match day analysis, for example, to enable complex strategic decisions. The author describes how sports informatics experts should always be consulted when adopting such a system so to best tailor their requirements

Poniszewska-Maranda et al. (2017) used the cloud to develop a cloud-based prototype application to organise snooker tournaments. Prior to this, the organisation had been doing so manually, costing a lot of time for many staff.

Amazon Web Services (2022) mention programs that their platform is used. First, one in which Bai & Bai (2021) highlighted as a challenge of cloud computing in sport, is the development of cloud-based programs to search for new fresh talent using data analysis. They also mention the reality of in-venue experiences that may include a second screen providing statistics on the games fans are already watching, and even the enhancement of the concession sales experience.

AWS looks ahead to how blockchain technology might be used in the sports industry, for example, by using Non Fungible Tokens (NFTs) or augmented reality that allows remote users to watch games as if they were there in the stadium. Finally, in addition to player tracking, which is used to gather statistics for players, ball tracking is being made available to provide additional data points.

# Conclusions

This literature review found that cloud computing offers two major contributions to applications in sport: OTT, and athlete health and performance analysis.

Within both branches, many of the limitations inherently come from the data sources themselves and the communications systems used to join them to the cloud. Health and performance analysis invariably uses IoT devices of some type in almost all cases, showing that IoT is now synonymous with cloud technology as a data input method.

Teams, individuals and fans can use cloud data analytics to learn how to win, and athletes can improve, train and recover better. Sports organisations are also using cloud information systems to run tournaments and make strategic decisions. The review also shows how cloud information systems may be used in the future of sport. Many of the papers note the importance of keeping data secure or data anonymisation in the cloud, something that initially can make users feel uneasy, with the loss of direct control of their data. This may be something they need to consider against the clear benefits that cloud computing and storage bring, not least the cost savings and data availability.

While many systems are using advanced algorithms such as machine learning and neural networks for data analytics, sports arenas do not yet have the capacity to facilitate thousands of fans connecting and using the Wi-Fi network simultaneously, and so in game experiences may still be limited to using edge networks or fog computing than fully utilising cloud services. This could also be argued as a positive however, as in a world where the opportunity of excitement is often lost in preference to mobile device screens.

There also seems to be a lack of research into talent identification, how smaller sports organisations, in particular, deal with cloud related problems such as vendor lock in, and the lack of cloud expertise to best adopt cloud information systems. Additionally, the literature seems very focused on developing physical performance and recovery, however lacks significant research into the psychological side of sport, including concentration, determination, decision making, etc.

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# Appendix

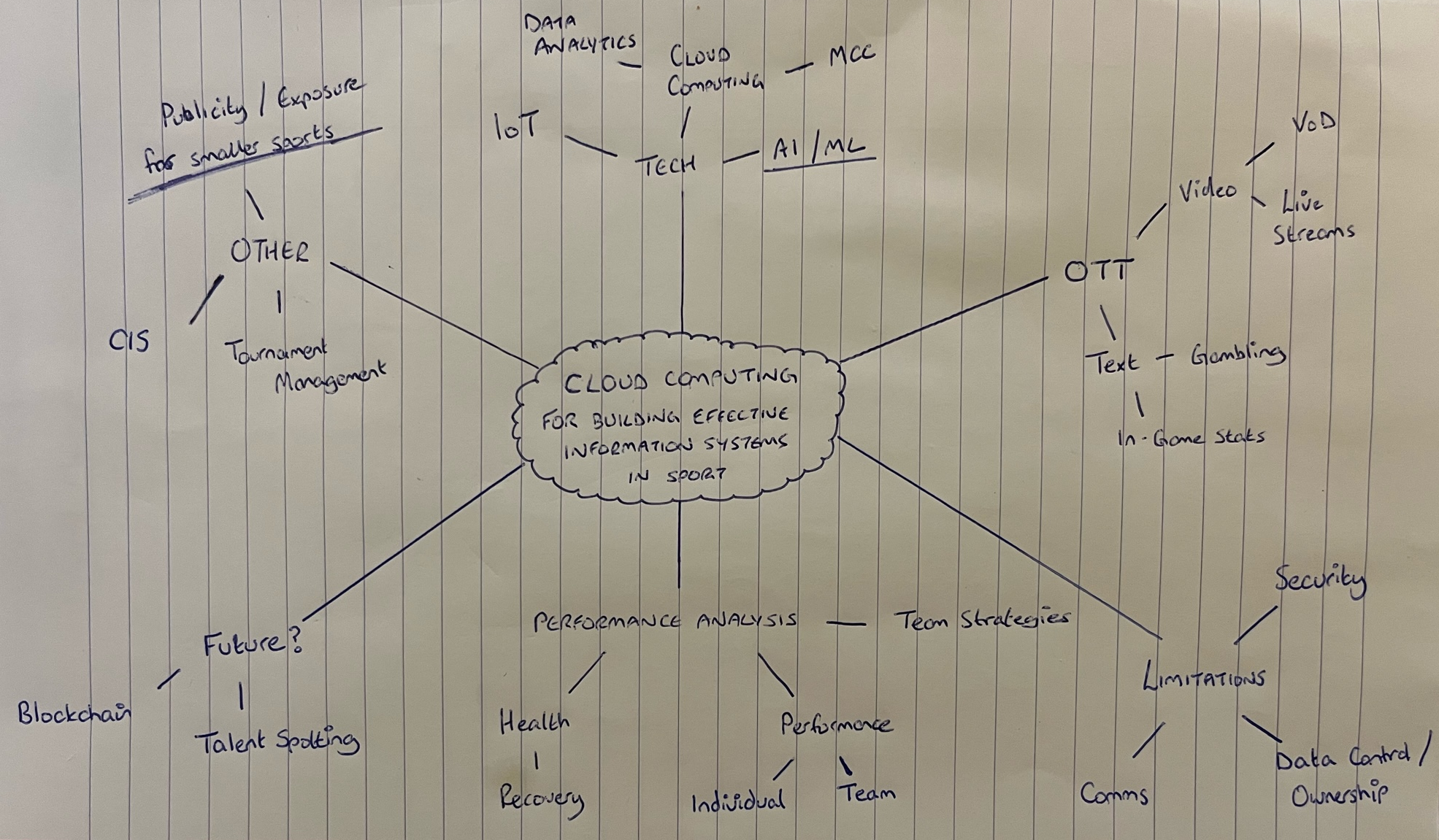


Figure 1: Research Territory Map