# Synchronous BIM Collaboration in the Cloud: benefits and challenges from the implementation of a bespoke solution

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## ABSTRACT

Building Information Modeling (BIM) technologies and processes enable different implementation levels or use stages with varying degree of integration (e.g. file-based collaboration, model-based collaboration). While there is no general agreement on the terminology to denote such levels or use stages, file-based collaboration and model-based collaboration – often called also integrated BIM – are the two levels being investigated in both academic research and industry applications. In file-based collaboration, project participants from a supply chain produce federated BIM models that are merged together for specialized purposes (e.g. design coordination) only at specific project lifecycle phases. In model-based collaboration, all participants work on a synchronized central model that is integrated and can be shared among them at project phase. Model-based collaboration represents a significant paradigm shift in industry practices. In recent years, much of the research in both BIM technologies and processes has been focused on BIM file-based collaboration. This research proposes a low cost IT platform that enables BIM model-based collaboration and a real world case study. The proposed platform and benefits and challenges from working in this environment are discussed in this paper.

**Keywords**: BIM, Virtualization, Cloud Computing.

## INTRODUCTION

Building projects in the Architectural, Engineering and Construction (AEC) require models from several project participants for their full design, engineering and construction. Depending on the implemented BIM technologies and processes, the collaboration among project participants can be classified as either file-based collaboration or model-based collaboration. Model-based collaboration requires the project participant to work on a central model and database. The approaches to enable model-based collaboration are through BIM servers and more recently through cloud computing. This distinction between BIM servers and Cloud Computing could be contentious without the explanation of the concept of virtualization. Virtualization or a virtual machine is a software abstraction of hardware computing resources (e.g. storage, CPU, etc.) to enable several virtual servers to be implemented in one physical machine that share the same hardware resources (Zhang and Issa, 2012). A BIM-server is a collaboration platform that maintains a repository of the building data, and allows native applications to import and export files from the database for viewing, checking, updating and modifying the data (Singh et al., 2011). Therefore, BIM servers can be considered as a form of BIM cloud computing with a low virtualization level. While several BIM servers (i.e. Autodesk Collaborative Project Management, Bentley ProjectWise Integration Server, i-Model, ProjectWise Navigator, etc.) are commercially available, most of them are still developing and do not fully enable object-level management (Eastman et al., 2011) which is advanced feature of model-based collaboration. The debate around what qualifies as "cloud computing" in other industries has also made its way into the AEC industry (Zhang and Issa, 2012). A general accepted definition is that cloud computing is remote control or software virtualization where the application is installed and run on the server side but controlled remotely by a user who can use the computing resources on demand and pay a usage fee (Zhang and Issa, 2012). This definition is in agreement with the definition of cloud computing that as a form of "computing resources available from a remote location which are generally accessed by users over the internet Cloud" computing university (2011). Early Project management collaboration platforms such as Online Construction Project Extranets can be considered as forms of cloud computing. However, to date BIM cloud computing platforms and services are still lacking the wide range of functionalities required by the AEC industry (e.g. compliance checking, energy analysis, quantity take-off, procurement, etc.).

The temporary nature of design team in the AEC and the relatively small size of the majority of consultancy firms make it sensible to research a low cost solution that enable model-based collaboration in the cloud. This paper proposes a solution, based on commercial cloud hosting extranet, to share integrated central and live model in the cloud. The paper presents the benefits and challenges of working in such an environment from a real world case study. This work was undertaken as a collaborative effort between the industry (i.e. Niven Architects and their supply chain) and academia (i.e. Teesside University) within a Knowledge Transfer Partnership (KTP) scheme. A KTP is a British government-supported scheme, which facilitates the interactions between a company base and an academic base, enabling businesses to use research outputs and skills of academic institutions to address and solve important business challenges.

## IT PLATFORM

The full design and engineering of each building project requires the collaboration between the lead architects and their consultants who are geographically dispersed and reunite in a temporary team for the specific project. In pre-BIM (e.g. 2d and 3d) and file-based collaboration delivery of projects, stakeholders exchange graphical and non-graphical data through the exchange of e-mails or the sharing of data on collaboration extranets. In the UK construction industry, file-based collaboration through federated BIM models is the level (i.e. level 2) mandated by the UK government on all centrally procured projects by 2016. Therefore, the most advanced AEC firms in the UK are at level 2. Any IT investment aiming at exceeding this level towards higher integration level (e.g. model based or integrated BIM) will require to be very effective from both economic and benefits perspectives. In such a context, the lead architects (i.e. Niven Architects), teamed up with a research institution (i.e. Teesside University), to assess the feasibility of adapting commercially available cloud hosting extranets in enabling live collaboration on a centrally shared file between all members of the supply chain. Three extranet platforms (e.g. SharePoint, Google Drive and Dropbox), that primarily offer general hosting services and files backup, synchronization and sharing, were shortlisted for testing. The selection of an extranet will be based on its capability to synchronize a centrally shared project model on the cloud with local federated files on the local servers of the lead Architects and their supply chain. Initial tests were conducted in the leads Architects firm by three design team members located in the same office but sharing their federated file through the cloud and aiming to synchronize them in near real-time – every time a local file is updated – with the central project model hosted on their local server. Following numerous experimental tests, in which sharing protocols (e.g. naming of central model and local files, timing for updates to reflect live synchronization, etc.) were ammended, the design team succeeded in enabling a centrally shared and integrated BIM model on the cloud. A key aspect that enabled this achievement was the identification of specific standards or convention for naming of files hosted on the cloud, on consultant local servers and on the lead Architects server. For commercial confidentiality, the naming standards and the selected hosting extranet cannot be disclosed in this outlet. The IT infrastructure is depicted in Figure 1 and is mainly composed from standard hardware components built around and linked to the web-based hosting platform.

If the proposed solution is assessed in terms virtualization level, discussed in the introduction, it is clear that the level is low and is obtained from virtualizing the storage of the synchronized central BIM model through the cloud hosting platform. Therefore, in terms of virtualization the proposed solution does not offer any advantage over BIM servers. However it is a much more cost effective solution compared to commercial BIM servers. Comparing the proposed solution with BIM cloud computing, the main advantage is that centrally-shared and synchronized BIM models use proprietary formats which is not currently possible with the few available BIM cloud computing solutions. However, the proposed solution lacks functionalities required in BIM-based projects and available in some commercial BIM servers such as the capability of updating and modifying at object level in the central model. A significant role in enabling the proposed solution to deliver synchronized central model in the cloud was achieved by the BIM Process Execution Protocols (BIM PEP) which defined the rules for interacting with the central model throuh exchanging information and synchronizing (i.e. when, what and how), the responsibilities for providing information, the file formats and the technologies that can be used. The research partners are currently assessing the feasibility of further developing and commercializing the proposed low cost solution for sharing a centralized BIM models in the cloud for proprietary BIM authoring tools.

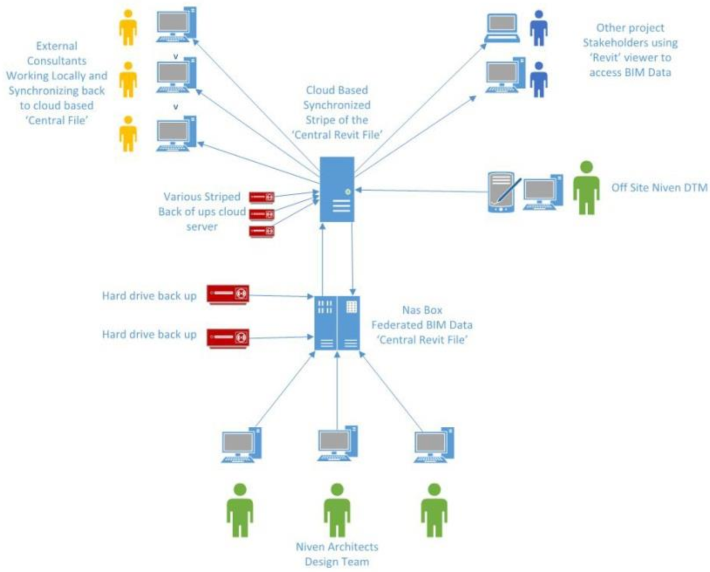


**Figure 1: Architecture of the low cost IT network for live BIM in the cloud**

## CASE STUDY

The case study was conducted on a real world mid-sized community developed project situated in the North East of England (Figure 2). The lead architects and their supply chain have all had prior experience of working in a BIM file-based collaboration environment (level 2). BIM PEPs developed by the lead architects were agreed by the supply chain in a BIM 'Kick-off' meeting to enable live collaboration on a central model in the cloud. The BIM PEPs established information exchange methods between the software platforms used in the project, responsibilities of different consultants in the delivery of the different level of details, naming standards and interaction with the cloud hosting platform. The BIM PEPs were made available to the entire design team who can refer to them at any point in time during the project execution. Working concurrently live on a centrally shared model in the cloud entails greater liability challenge compared to file-based collaboration. In this case, in addition to the protocols dictating the processes for working in the central live environment, there were functionalities in the cloud hosting platform such locking information to other users and restricting editing rights in the live environment (i.e. each design discipline receives up-to-date design information about other disciplines but can edit their own design information only). This helps avoiding some of the liability and intellectual property challenges. A snapshot from the live modelling environment is shown in figure 3. In that instance, six design team members from three disciplines were working at the same time on the model. The design activities, undertaken by the design team members, had to be first completed and then synchronized with the central model as the intent was to synchronize and share completed design activities and not work in progress. At the completion of project design activities, a workshop between all members of the supply chain was held to discuss the benefits and the challenges from working in such an environment which are summarized in the subsequent sections.

**Figure 2: A community development project as a case study**

**Figure 3: A screenshot from the cloud live environment**

***Benefits***

- The BIM project coordinator was able to monitor design team information as it was produced. A piping work designed by the Mechanical and Electrical (M&E) consultant was immediately identified as having a wrong height and positioning with the integrated model (Figure 12). This design error was rectified within a few minutes without a significant amount of aborted works.

- All stakeholders had up-to-date design information at any point in the project. The 3D digital model and their data information were live within the cloud-based storage platform. Although the project official contractual documents require the issue of design information at specific dates, information in this design environment could be extracted by the client or any project stakeholders at any time.

- Communication between the design team increased ‘exponentially’. In file-based collaboration, communication occurs when a design file is issued by a stakeholder and accessed by another stakeholder via emails or file sharing extranets. In this case, all design team members working together in the same live environment can continuously monitor the progress of each other through the central model and discuss it via Skype or over the phone. There was a feeling described by project participants “as if we were all working in the same office”.

- The platform allowed the BIM coordinator and project manager to monitor the actual progress and outputs in each design discipline. The use of this functionality to make judgment about the design progress was questioned by some participants as workload prioritization varies between different organizations.

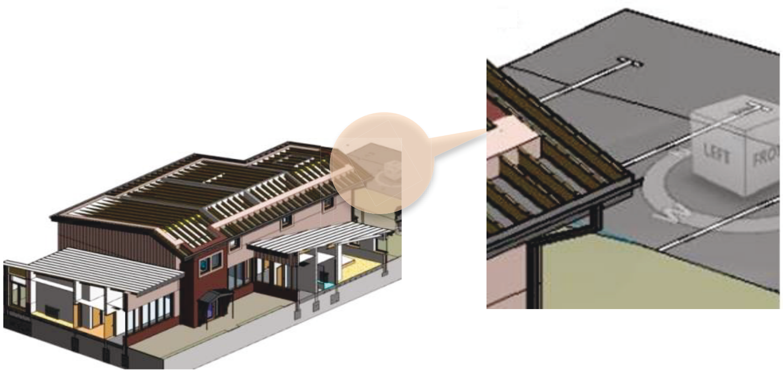

**Figure 4 Immediate identification of design error in the piping work**

***Challenges***

- The process of producing design and synchronizing it in real-time to a central model shared in the cloud bypassed all firms' internal quality assurance processes (e.g. ISO 9001). This was a key concern for all project participants. The traditional method of a drawing being produced by a draftsman and checked by a senior architect before it is formally issued was completely lost. All information inputted to the central shared model in the cloud was live and accessible by all design team members. To partly address this challenge, it was agreed to use only specific dates of the live model where drawings issues form contractual conditions. However, this solution did not wipe out totally the concern of the design team.

- Some IT infrastructure related issues were encountered. The computing power and performance of computers used in some of the supply chain firms were not up to date and could not handle large models. However, this is a generic issue and is not inherent in the proposed solution for sharing live central model in the cloud. The broadband performance occasionally affected the speed of uploads and downloads which is also a general infrastructure issue. A technical issue inherent in the proposed solution occurred when with the platform was when work-sets were claimed by two users at the same moment without data being synchronized. However, this issue could be resolved by adding apposite rules to the BIM PEPs.

- Together the varying speed of design production processes between different firms and the lack of clarity in terms of responsibilities for rectifying design errors caused some significant coordination issues which affected the integrated central model. For example, at the early stages of the project all design teams were working on the project at the same time resulting in all work items progressing at the same speed. At a certain point, there was a lag with the architectural drawings two week ahead other disciplines. As each discipline's work-set is locked to other disciplines, some clashes were originated. For example, in figure 5 some M&E pipes appeared outside the building fabric as a result in the position change of the building boundary. These issues are more process related and can be addressed in BIM PEPs.

**Figure 5: Pipe work outside of Building fabric**

## CONCLUSIONS

Synchronous BIM model collaboration in the cloud is an emerging and challenging area for AEC researchers and practitioners. This paper proposed a low-cost platform that exploits commercial cloud hosting extranets to enable the sharing of a live central integrated model between geographically dispersed design teams. The real world case studies proved that such synchronization and sharing of design information is possible although some quality assurance and coordination challenges were encountered. In particular, the proposed system bypasses all quality assurance systems of participants and presents some coordination issues when the design team progress at different production rates. Such challenges are process related and can be overcome by the design of apposite BIM process execution plans.

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