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## ENGINEERING AND TECHNOLOGY

# Numerical simulation of server farm thermal transport phenomena

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## Abstract

A server farm is a collection of network servers that are all housed in the same physical location. A server farm combines the computational capacity of several servers by running one or more applications or services at the same time. Because the servers are kept so close together, the system requires efficient cooling system to dissipate the heat produced. Inefficient cooling system can result in degradation of server performance or even total failure of the server. Therefore, efficient cooling system is essential to minimize system failure while optimizing the performance. The aim of this study is to model the heat transport phenomena of a server farm run by Telekom Malaysia (TM) as part of the TM city project. Ansys-Fluent was utilized to simulate the heat transport processes. Heat dispersion across the server farm was assessed using Ansys-Fluent via the heat contour mapping while airflow across the room was simulated using the streamline vector plot. It has been discovered that utilizing the original design, cooling air distributed at the front of the server racks can reach a maximum temperature of 27°C, which is the maximum permissible temperature according to ASHRAE recommendations. Similar temperature was also taken during daily operation of the server farm to validate the simulation data. From the streamline vector plot, it can be seen that this is primarily due to recirculation of hot air from the back of the server racks into the cold aisles. Thus, it is recommended that a cold aisle containment system be implemented to solve this problem.

*Keywords: - Computational fluid dynamics (CFD), server farm, thermal management, fluid dynamics, computer room air conditioning, Ansys-Fluent*

## 1. Introduction

A server farm is a collection of network servers that are all housed in the same physical location. A server farm combines the computational capacity of several servers by running one or more applications or services at the same time. Server farms, which are frequently made up of thousands of computers, require a lot of power to run and stay cool. To operate efficiently, the TM city server farm requires efficient cooling. This is important to increase components lifecycle and reduce server downtime. Every data centre aspires to achieve zero downtime and maximum server efficiency and this can be accomplished by properly optimising and maintaining the components involved. Server's downtime or failure can be caused by a variety of factors, one of which being overheating. Overheating occurs when a server's temperature rises above its maximum working temperature, resulting in decreased performance, data loss, or even the server's complete failure. According to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), a server farm's recommended temperature range is 18 to 27°C, with maximum allowed temperatures ranging from 15 to 32°C (ASHRAE, 2016).

According to recent statistics from the TM city server farm, numerous server racks are operating near the maximum recommended temperature. This is especially true for servers on the upper levels of the racks, where cold air has dissipated and mixed with hot air recirculated from behind of the server racks. This results in isolated hotspots across the server farms, lowering system performance and shortening the life cycle of adjacent components. To further understand the phenomena, a numerical study was performed utilizing available data to replicate the server farm thermal transport phenomena.

The server farm environment was simulated and evaluated using Ansys-Fluent to generate a temperature distribution map and airflow vector plot of the server farm. The results were then used to see if there are any hotspots or excessive hot air recirculation. At the conclusion of the report, a plan of action to address the problem was also proposed.

## 2. Literature review

Servers are typically configured or arranged with the goal of separating the hot and cold aisles. This is done to decrease the mixing of hot and cold air, resulting in a lower feeding temperature at the server rack's front. Higher feeding temperatures result in worse cooling efficiency and, as a result, higher server operating temperatures. The hot and cold aisle design, which involves positioning IT equipment racks in rows so that the rack fronts face the cool aisle and exhaust is routed to the hot aisle is recommended by ASHRAE. This design (figure 1) minimises the mixing of hot and cold air and maximises heat dissipation (Bhatia, 2015). The hot and cold aisle design is already employed in the TM City server farm. However, there is no containment system in place.

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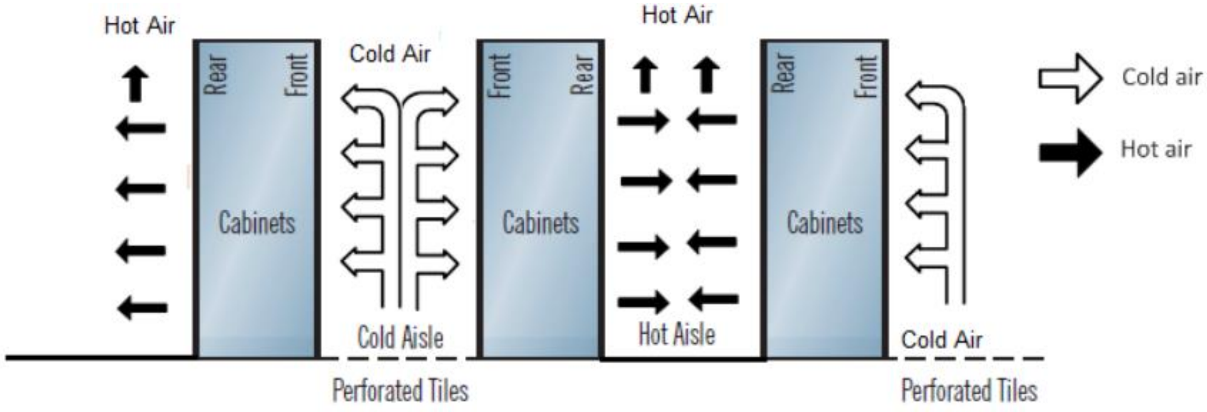


Figure 1: Cold and hot aisle configuration( (Bhatia, 2015)

It is hypothesized that without a containment system, the topmost racks will receive less cold air due to the mixing of hot air from the back of the rack with cold air at the front of the rack. This is why it's critical to utilise either a hot or cold containment system. Increased cold air supply temperatures and the warmest possible return air to the cooling unit are both attainable with containment. Better heat exchange across the cooling coil, increased cooling capacity, and overall higher efficiency are all advantages of a higher return temperature to the cooling unit.

Furthermore, containment lets the supply air from the cooling unit to reach the front of the server equipment without mixing with the hot air. As a result, server inlet air temperatures are more consistent. (John Niemann, 2015)

**3. Methodology**

The TM city server farm 1 has 96 server racks, six computer room air conditioning units (CRACs), and four remote power panels (RPP). The server racks are organised in single and double lanes, with the CRAC providing cooling air from beneath the raised floor. The room's measurements are 24 meter in length, 16-meter-wide and 4 meter in height. The server farm's environment was modelled using the Autodesk Inventor, and figure 2 depicts the server farm's wireframe model.

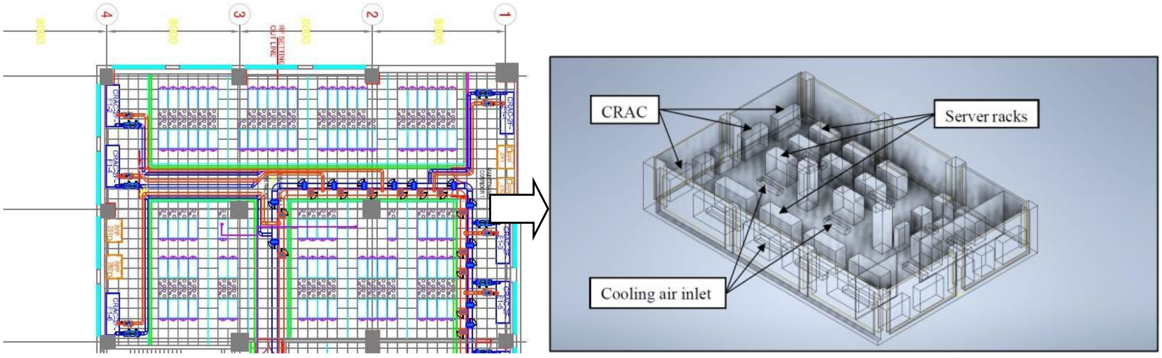


Figure 2: TM City server farm modeled in the wireframe view

All components in the server farm are modelled as black boxes to simplify the simulation. As a result, the airflow inside the server racks, crac, and beneath the raised floor is not modelled. The airflow inside the space and over the components are the only issues that need to be addressed. All of the components are also assumed to be rectangular in shape, without cables and lights. The heat fluxes are applied to the inlet and outflow of the server racks and CRACs, as well as the corresponding walls, to provide the boundary conditions.

The fluid domain was constructed using the boolean function after the 3-Dimensional model was imported into Ansys design modeler. Figure 3 shows how the fluid domain was discretized into smaller meshes. Due to the relatively basic shape of the server farm components, the hexahedral mesh was employed. The fluid domain is discretized into smaller rectangular boxes which are connected by edges and vertices. The edges and vertices are then shaped to fit the components' surfaces. The average mesh size parameter in Ansys Fluent is used to manage the amount of meshes. Because of the vast scale of the server farm, bigger mesh sizes (30cm) were initially utilised. Then, to improve the output, a smaller average mesh size (15cm) was chosen with 473,660 nodes and 475,063 elements in total. Figure 3 depict the discretized fluid domain. The aspect ratio of the mesh is kept as near to 1.

However, there are certain deviation due to the dimensions and the components geometry in the server farm. A more accurate simulation will require further mesh refinement.

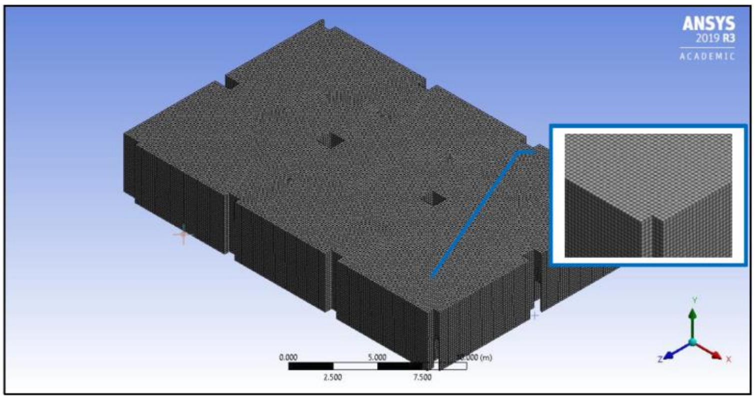


Figure 3: The discretized fluid domain - average mesh size of 0.015m, hex dominant mesh with average orthogonal quality of 0.92046 and average skewness of 0.12689

The server farm's walls, floor, and ceiling are assumed to be adiabatic for the sake of this study. This means that no thermal energy enters or leaves the server farm. It's also assumed that there's no air leakage between the server farms and components. The heat flow throughout the server farm is modelled using thermal energy. Then, within Ansys-Fluent the boundary conditions are set to replicate the thermal transport phenomena and calculation were run for the maximum of 3000 iterations or until the convergence of residuals. Figure 4 highlights the flow chart for the simulation processes.

### 3.1 Flow chart

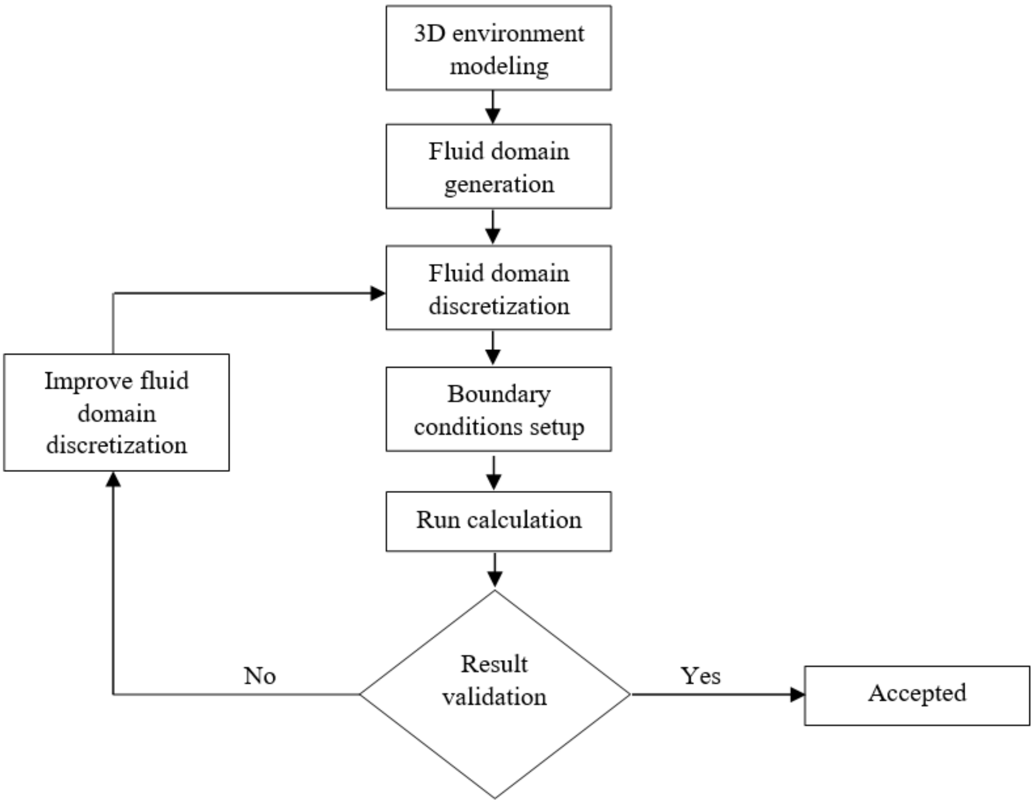


Figure 4: Flow chart of the simulation processes

## 4. Finding and analysis

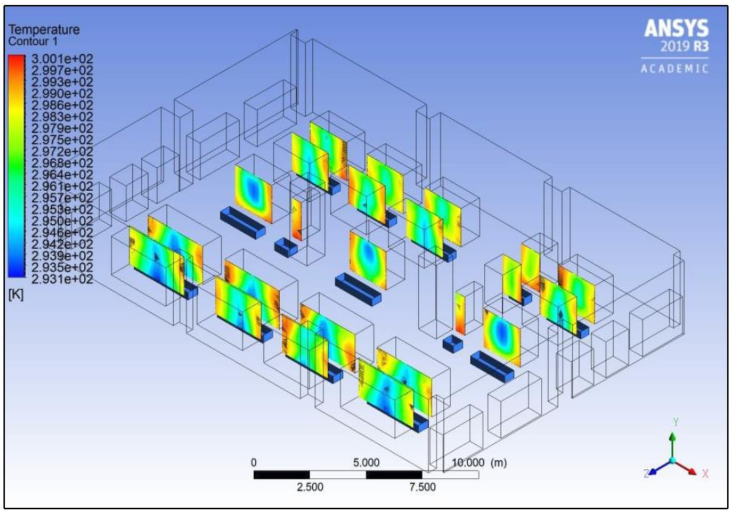


Figure 5: Temperature distribution in front of the server racks

As shown in figure 5, the temperature in front of the rack fluctuates from 20°C to 27°C with the original setup. The temperature distribution on most racks may be seen to be lowest on the lower half of the rack and greatest on the upper portion and sides of the racks. This is due to the cold air coming from beneath the floor through the raised floor inlet, which warms up when it comes into touch with the server wall and flows up intermixing with warm air around the server racks. Recirculation of hot air from the back of the server racks into the rack intake on the cold aisle is also responsible for the temperature rise on the side of the racks. This is a phenomenon commonly occurring with server farm without a containment system installed. Similar case was also reported by E. Wibron in her theses CFD Modeling of an air-cooled data centers. Warmer air is produced at the borders of the server racks as a result of the mixture of hot and cold air. Figure 6 depicts the exhaust air streamline, which can be used to confirm this.

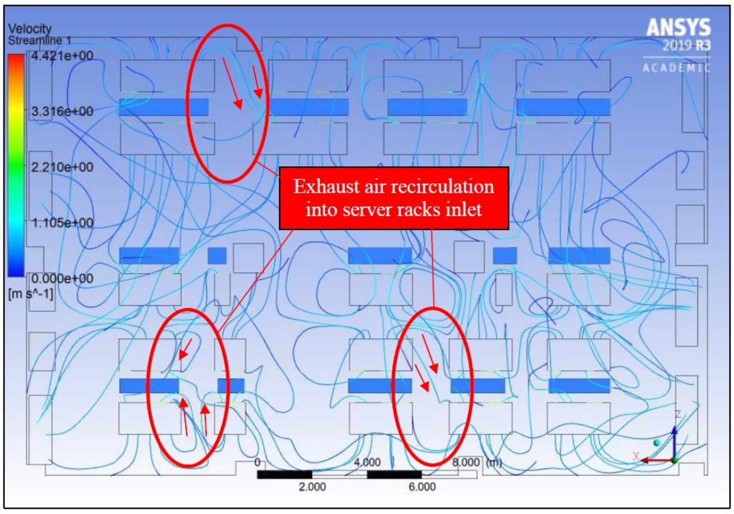


Figure 6: Streamline flow of exhaust air from the back of server racks

On most sides of the server racks, the reverse flow is present. This is also due to the suction force caused by the server racks' internal fan. The increased velocity of the streamline as it approaches the front section of the server racks confirms this.

The highest temperature on the server racks is 27°C, which is on the edge of the maximum recommended temperature as stated by ASHRAE in its white paper TC9.9. Thus, a method to increase server rack cooling efficiency are required.

Aside from that, the thermal contour of the floor at various elevations can be used to gain more insight into the room's heat dispersion. The elevations are 0.1 meter – at floor level, 1.05 meter - mid rack height, and 2.02 meter as indicated in figure 7.

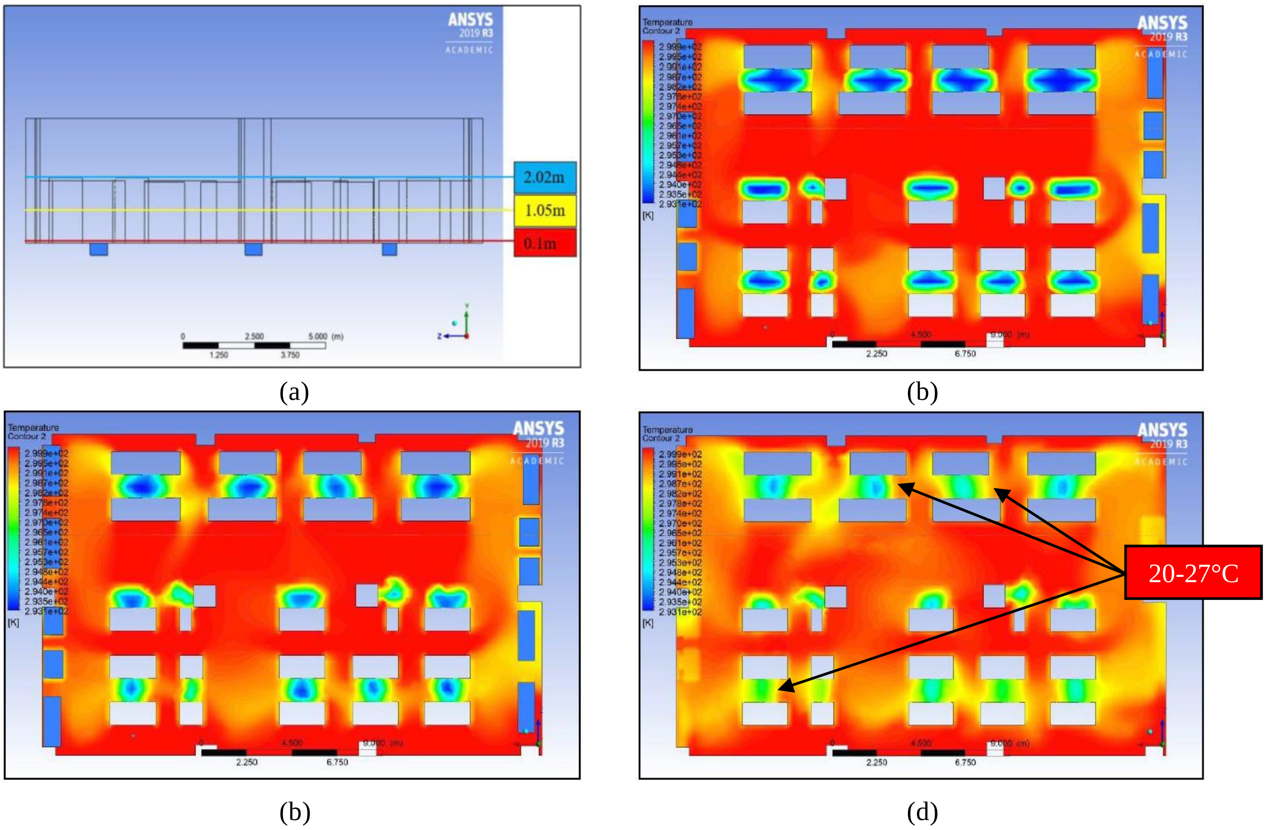


Figure 7: (a)Different horizontal planes used for thermal contour plot. (b),(c) and (d) contour plot at 0.1m,1.05m and 2.02m respectively.

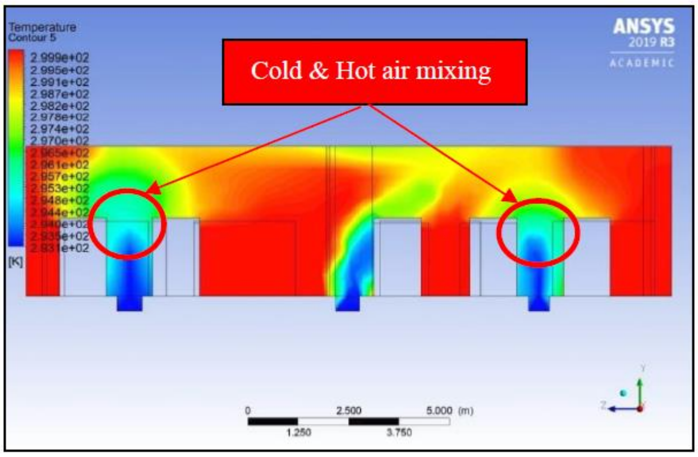


Figure 8. Thermal contour on vertical plane across the server farm

From figure 7, it can be seen that the flow of cold air from the raised floor inlet is sufficient to provide cooling from the lower to the top racks for most server racks. However, as in figure 8 there is some hot air recirculation over the tops of the server racks in the vertical plane. The recirculation of hot air from the server racks' sides and tops will mix with the cold air, eventually raising the cooling air temperature. As a result, a simple approach such as constructing a cool aisle containment system is recommended to prevent hot air recirculation.

## 5. Conclusion

The server farm's three-dimensional (3D) environment had been successfully modelled from the 2D design. However, because all components are assumed to be rectangular in shape and simulated as black boxes, the resulted simulation is a simplified version of the actual server farm. The purpose of this simplification is to reduce computational power and calculation time. However, the simplifying procedure can lead to a loss of precision. The simulation result should always be reevaluated by comparing it to the actual server farm measurements.

The server farm's thermal transport phenomena were successfully simulated using Ansys-Fluent. The velocity streamline plot was also useful to visualize the airflow throughout the server farm. The average temperature and localised hot spot in front of the server farms were successfully simulated and identified. The temperature map shows that the increase in temperature happens primarily on the side and top of the server racks. The temperature on the server racks' sides and tops can reach as high as 27°C. The temperature rise is primarily due to hot air recirculation, as can be seen in the velocity streamline.

To address this issue, it was suggested that the server farm be outfitted with a cold aisle containment system. A similar simulation with the cold aisle containment system modeled in place is also proposed to be performed. This will be beneficial as a part of the cost-benefit assessment prior to the actual installation.

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