Airflow Modeling
An Effective Tool for Improving Cooling Performance of Data Centers

Amir Radmehr and Kailash Karki
Innovative Research, Inc.
Plymouth, MN 55447

Background

With continuing increase of heat load in data centers, facility managers are facing greater challenges to prevent equipment failure due to overheating, which requires that the servers be properly cooled. Although in today's data centers the cooling infrastructure consumes an enormous amount of energy, in most cases the cooling systems are not working efficiently. Some of the reasons for the inefficient operation are as follows:

1- The cooling airflow is not distributed according to the demand of the equipment.
2- An unacceptable amount of the cooling air short circuits back to the CRAC units without participating in the cooling of the servers.
3- The hot air discharges from racks is not contained and migrates to the inlets of the racks.
4- In raised-floor data centers, a substantial amount of the cooling air leaks through cable openings or gaps between floor panels.
5- The placement of the cooling units does not take in consideration the return path of the hot air.

Optimization of the cooling system can significantly reduce the cooling-related energy consumption and emission of green house gases.

Airflow and temperature modeling, based on Computational Fluid Dynamics (CFD) technique, is an effective tool to optimize the cooling performance of an existing data center. Also, it can be used to design new data centers with higher efficiency and lower energy consumption. There are different methods for improving the cooling performance of a data center. Implementing these methods require different time and capital investments. Since each data center is unique in terms of design, space, available budget, and flexibility to change, one needs to examine these methods carefully and select the ones that meet the specific requirements of a data center.

Some of the techniques that can be used to optimize the cooling performance of a data center are listed below:

1- Using hot aisles-cold aisles arrangement.
2- Closing the cable cutouts and other openings to minimize the leakage flow.
3- Placing the under-floor obstructions in a manner that does not adversely affect the airflow distribution.
4- Using the return plenum.
5- Closing the end of the cold aisles to minimize the infiltration of hot air.
6- Using blanking panels to close the open spaces between servers or between racks.
7- Increasing the return temperature of the CRAC units to increase their efficiency
8- Using exhaust ducts over racks
9- Using aisle containment systems

The goal of this paper is to show how airflow modeling can be used to demonstrate the effectiveness of some of these techniques. A commercially available software product, TileFlow ™, is used to create the data center models and obtain the results.

In the interest of space, only selected techniques will be examined here. For each case the cooling performance of the data center is evaluated before and after implementing the technique.

Case Study 1: Closing the cable cutouts

In a raised floor data center, a large amount of the cooling air is wasted through the cable cutouts. Closing these openings reduces the leakage, raises the plenum pressure, and increases the amount of the airflow in front of the racks.

Figure 1 shows the plan view of a data center, which utilizes the hot aisle-cold aisle arrangement. This is a high-density data center with a heat load of 120 Watts per square feet. There are six CRAC units located along the perimeter walls, which provide a total of 30,000 CFM of cooling air to the under-floor plenum. There is one perforated tile in front of each rack. The tile located at the back of each rack has a 5 in. x 9 in. cable cutout.

There are 29 server racks in this data center. The total heat load of all server racks is 222 KW and their airflow demand is 29,000 CFM. The total amount of the cooling air supplied by the CRAC units meets the airflow demand of the racks.

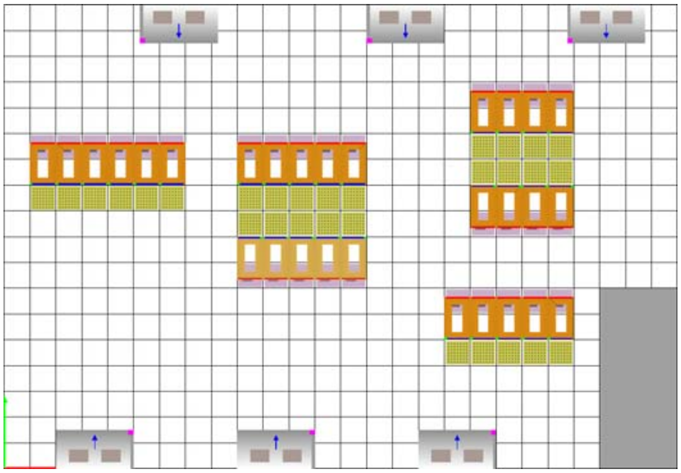

Figure 1- Plan view of the data center

Figure 2 shows the airflow distribution through perforated tiles and cable cutouts. A large amount of the airflow discharges through the cutouts. The total leakage flow through the cutouts is around 30% of the supplied air.

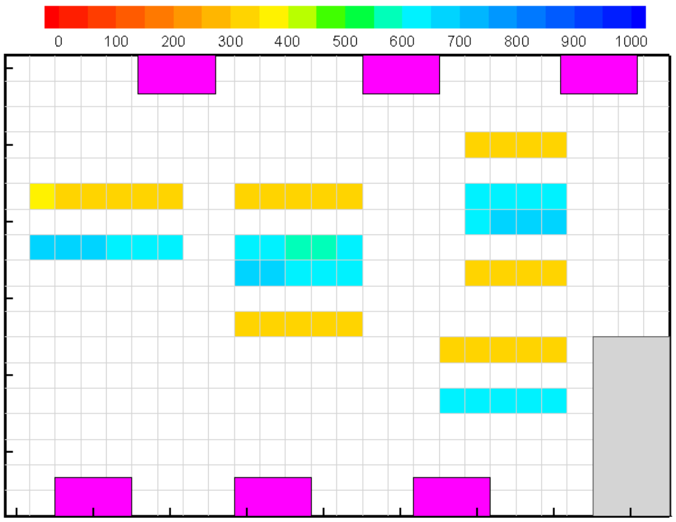

Figure 2- Airflow distribution

Figure 3 shows the three-dimensional view of the data center. It shows the temperature distribution on the front face of the racks. The cooling air discharged through the perforated tiles does not reach to the top of the racks. Therefore, the servers located near the top of the racks draw the room air.

Figure 4 shows that the hot exhaust air penetrates to the inlet of the racks from top. Racks located at the end of the row take the needed air from sides.

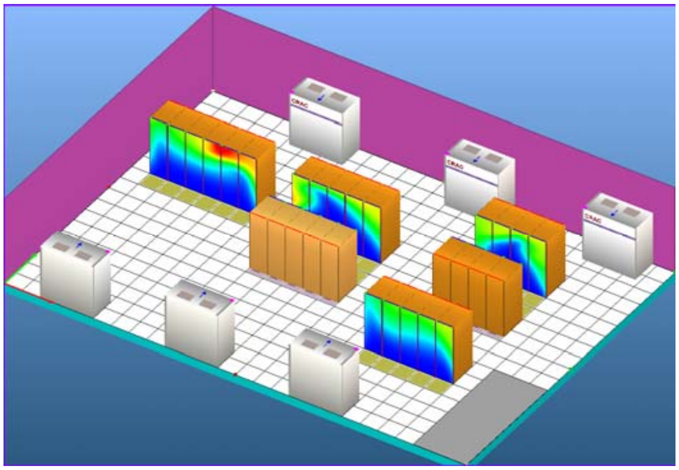

Figure 3- Temperature map on the front face of the racks

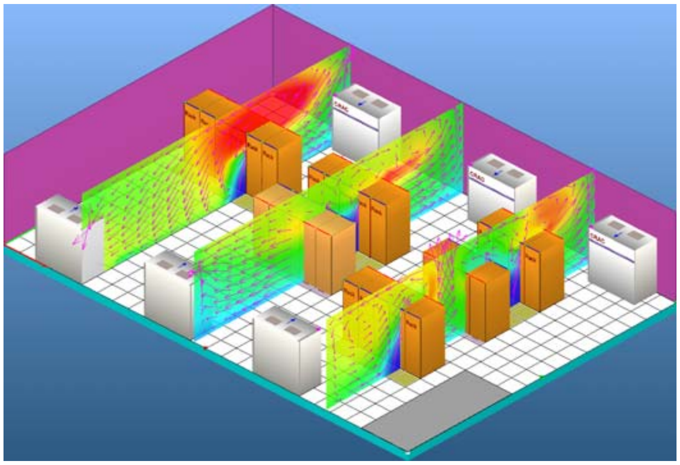

Figure 4- Penetration of the hot air to the inlet of the racks from top

Figure 5 shows the penetration of the hot air to the cold aisles from the sides.

Figure 6 shows the airflow distribution through the perforated tiles after closing the cable cutouts.

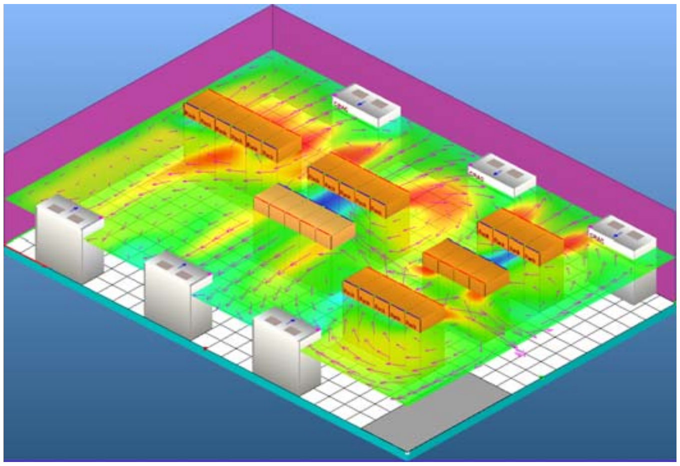

Figure 5- penetration of the hot air to the cold aisles

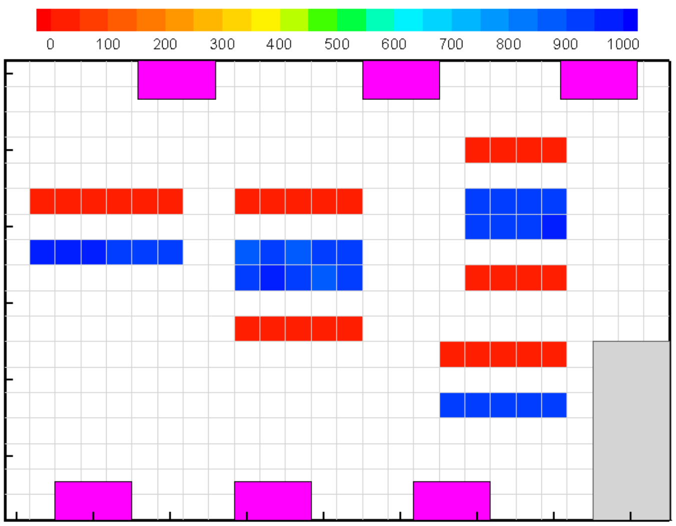

Figure 6- Airflow distribution after closing the cutouts

The leakage flow through the cutouts is eliminated and the airflow through perforated tiles is increased significantly.

Figure 7 shows the temperature distribution on the front faces of the racks after closing the cutouts. A significant improvement is shown compared to the case where the cutouts were open.

For most of the racks, the cooling air reaches to the top of the rack. However, as is shown in Figure 8, still a portion of the hot exhaust air penetrates to the inlet of the rack from the open ends of the cold aisles. This is a very common problem in most data center and is the subject of the second case study here.

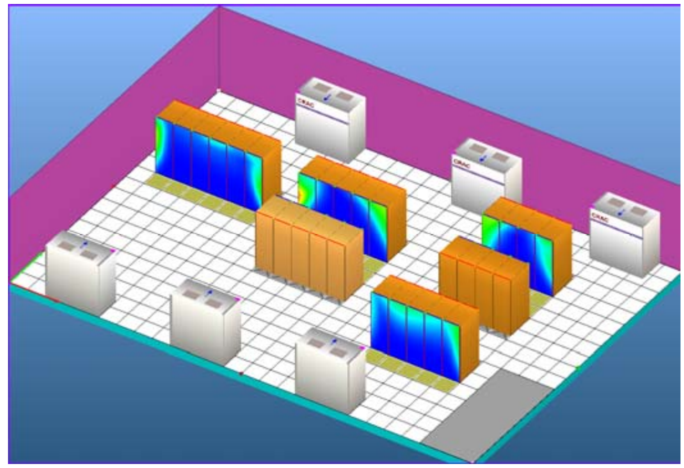

Figure 7- Temperature map on the front face of the racks

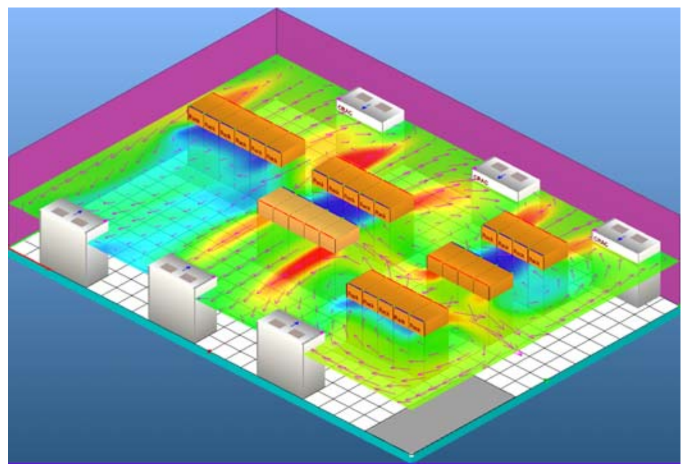

Figure 8- penetration of the hot air to the cold aisles

Case Study 2: Closing the end of cold aisles

As shown in Case Study 1, it is very common that the air from the hot aisle enters to a cold aisle from the open ends of the aisle. Thus, the racks located at the end of the row will be affected by the hot air penetration. Another negative effect is that the hot air drives the cold air to the middle of the cold aisle, where there is already enough cooling air. The extra cooling air at the middle of the cold aisle escapes from the top of the cold aisle without contributing to cooling of any heat load. This effect is shown in Figure 9.

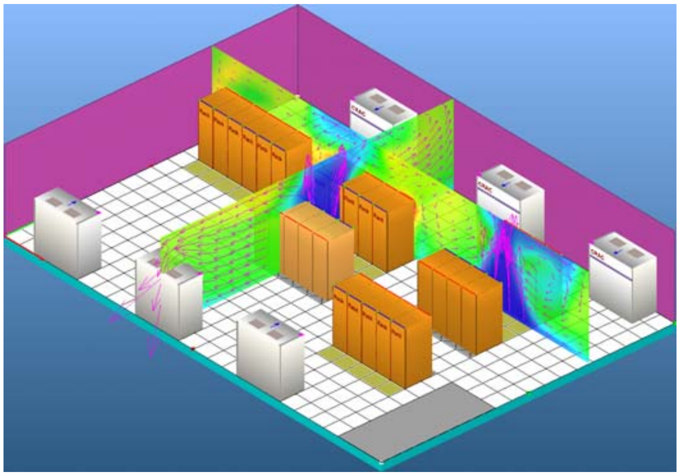

Figure 9- Wastage of cold air from the middle of the cold aisle

Closing the end of cold aisles eliminates these effects. Figure 10 shows the same data center while the ends of the cold aisles are closed by partitions. It can be seen that the available cooling air in front of the racks is being used completely (i.e. no wastage of the cold air) and the hot air penetration from the sides is eliminated.

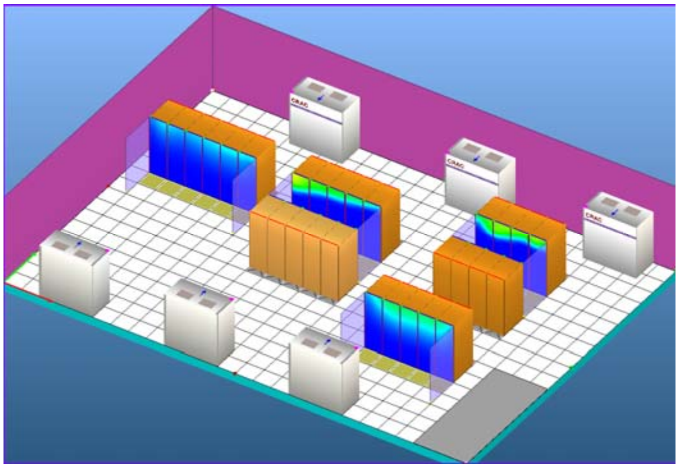

Figure 10 Temperature map on the front face of the racks after closing the end of the cold aisles

Conclusion

It is shown that the airflow modeling based on the CFD technique can be used to identify and resolve the cooling problems in data centers. By using airflow modeling technique, the cooling performance of existing data centers can be improved and highly efficient data centers can be designed.