How Overhead Cabling Saves Energy in Data Centers

White Paper 159

Revision 0

by Victor Avelar

> Executive summary

Placing data center power and data cables in overhead cable trays instead of under raised floors can result in an energy savings of 24%. Raised floors filled with cabling and other obstructions make it difficult to supply cold air to racks. The raised floor cable cutouts necessary to provide cable access to racks and PDUs result in a cold air leakage of 35%. The cable blockage and air leakage problems lead to the need for increased fan power, oversized cooling units, increased pump power, and lower cooling set points. This paper highlights these issues, and quantifies the energy impact.

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Introduction

Although not considered a best practice from an energy efficiency point of view, a common method for cooling data center equipment is to utilize a raised floor as a plenum for the delivery of cold air to the intakes of servers. The cold air is forced underneath the floor by fans within air handlers. However, this method is not the only option. Many new data centers today forgo the expense of the raised floor and place equipment on a hard floor. They cool their servers by utilizing in-row, overhead, or room air conditioning with hot aisle containment. The hard floor approach also forces the issue of placing cables overhead and many data centers have become accustom to working with overhead cables.

In both cases, the data center owners have to resolve the issue of how to lay out power and data cables. Data centers that depend on raised floor cooling distribution often route network data and power cabling underneath the raised floor. This cabling then feeds individual IT racks through cable cutouts at the back each rack. These cable cutouts allow cold air to bypass the IT server inlets at the front of the racks and mix with the hot air at the back of the rack. This design practice can lead to hot spots, clogged floors, and overall lower cooling system efficiency.

This paper analyzes the effect of under-floor cabling on cooling and on electrical consumption and concludes that **the decision to place network data and power cabling into overhead cable trays can lower cooling fan and pump power consumption by 24%**.

Under floor cabling energy waste

Under-floor cabling contributes to energy losses in three ways:

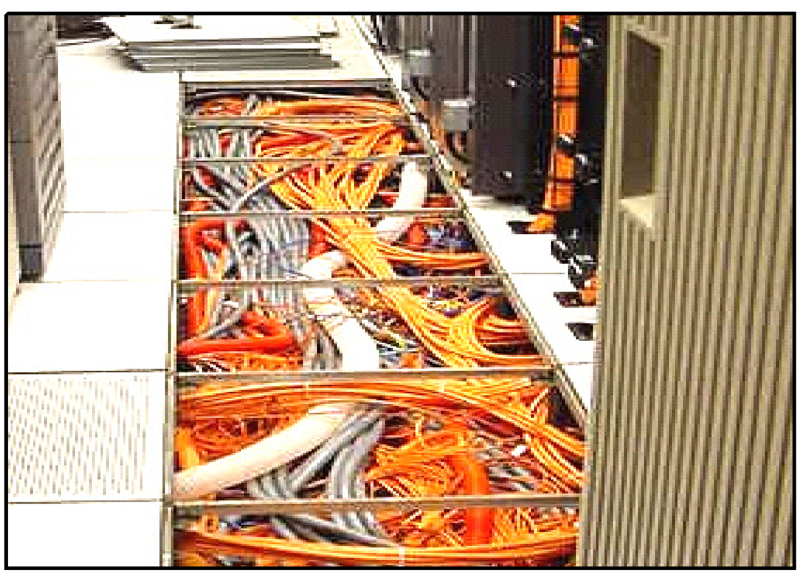
- Blockage of air due to cables
- Bypass air from rack cable cutouts
- Bypass air from power distribution unit (PDU) cutouts

Blockage of air due to cables

When new network or power cables are added under the floor, older unused cables are rarely pulled out to make room. Instead the cables are left undisturbed to minimize risk of down-time. The build-up of cables causes blockages in air flow which contribute to hot spots in the data center (see **Figure 1**).

Figure 1

Under floor cables are obstructing the flow of air in the raised floor plenum



A common solution is to add more air conditioning–not for cooling capacity–but for extra fan power to increase static pressure and overcome the under-floor blockages. The raised floor hides the build-up of cables over time. In contrast, overhead cabling is visible and is more likely to be properly maintained and managed over the years.

"When new network or power cables are added under the floor, older unused cables are rarely pulled out to make room. Instead they are left undisturbed to minimize risk of downtime."

Bypass air from rack cable cutouts

Under-floor cabling requires that cables come up through the floor tile and through the bottom of the rack. Cable cutouts in the tile measure about 20x20 cm (8x8 in) and are only partially filled with cabling. The remaining space is usually left open allowing cold air to leak into the hot aisle (assuming a hot / cold aisle layout).

The hot aisle should be the space where the hottest air in the data center makes its way back to the computer room air handler (CRAH). The cold air that leaks into the hot aisle lowers the air temperature back to the CRAH which decreases its capacity to remove heat. For example, a CRAH unit with 27°C (80°F) return air temperature provides 70kW of heat removal capacity. However, at a return air temperature of 22°C (72°F), the heat removal capacity drops to 43kW. The capacity lost due to bypass air may create hot spots which are sometimes addressed by adding more CRAH units.

Bypass air from PDU cutouts

Many PDUs are configured with four 42-position panels which means up to 168 individual circuits can be distributed to the IT racks. In addition to these conductors, large input conductors feed the PDU. Installation and removal of these conductors requires a 0.8-1.5 m^2 (9-16 ft^2) opening underneath the PDU. This bypass air from around conductors has the same negative effect on the cooling system efficiency as the bypass air from rack cable cutouts (see **Figure 2**).

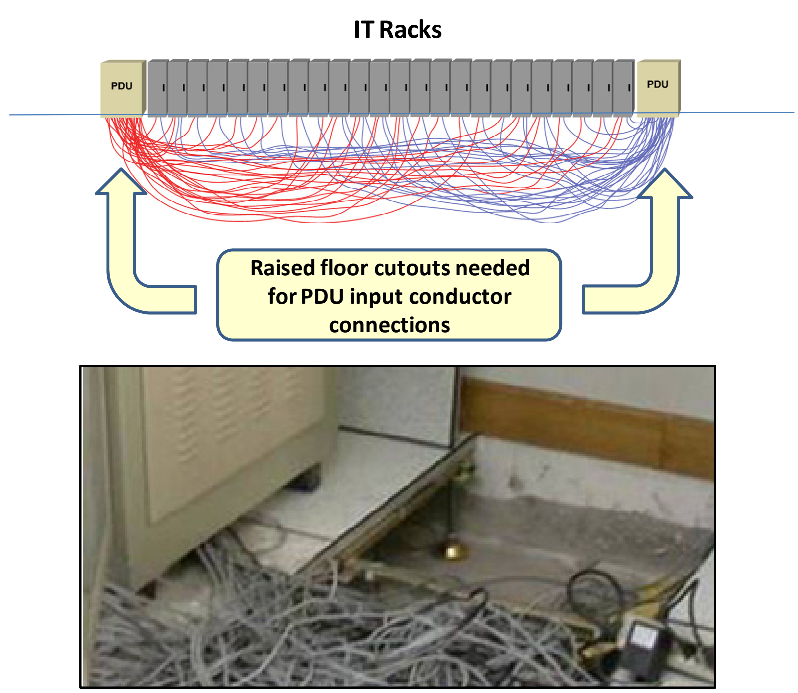


Figure 2

Cutouts and missing floor tiles are major sources of cold air leaks

Energy savings of overhead cabling

The energy savings attributed to overhead cabling are derived from lower fan losses and lower pump losses. Chiller energy cost savings can also be realized when the chilled water supply temperature is increased. A hypothetical data center was modeled to evaluate the savings in moving network and power cables to overhead cable tray. The assumptions used for the analysis include the following:

- Data center capacity – 1 MW
- Cooling system – chilled water
- Constant speed CRAH fans
- Rack inlet temperature with under floor cabling – 18°C (65°F)
- Rack inlet temperature with overhead cabling – 20°C (68°F)
- Average rack density – 2 kW/rack
- IT Equipment ΔT – 11°C (20°F)
- Quantity of IT racks – 500
- Average cable cutout area per rack – 0.03 m^2 (0.33 ft^2) - This is conservative since the 8"x8" cutout is filled by some cable
- Total rack cable cutout area – 15 m^2 (167 ft^2)
- Minimum airflow required for IT – 56,652 L/s (120,038 CFM)
- Hot air recirculation – 5% of airflow required for IT
- Average CFM at the front of each rack – 113 L/s (240 CFM)
- Open area of 25% open perforated tile – 0.09 m^2 (1 ft^2)
- Average velocity at the front of each rack – 73 m/minute (240 ft/minute)

In this analysis, a 1MW data center at 100% load is assumed to have 500 IT racks at an average power density of 2kW/rack. **Table 1** shows the calculated area of open tile cutout space and the associated air leakage as a percent of total required IT airflow. It is clear that the cable cutouts behind IT racks contribute the largest amount of cold air leakage in data centers with raised floor cooling.

Table 1

Tile cutout space with under floor cabling vs. overhead cabling as % of total required IT airflow

Location	Under floor		Overhead	
	m^2 (ft^2)	% leakage	m^2 (ft^2)	% leakage
Behind IT racks	15	33%	0 (0)	0%
Under PDUs	2 (20)	4%	0 (0)	0%
Behind CRAHs	8 (88)	18%	6 (65)	13%
Total	25	55%	6 (65)	13%

Moving the power and data cabling overhead reduces the total leakage to 13%. This significant reduction in leakage causes the CRAH return temperatures to increase, which then increases the cooling capacity of each individual CRAH, which ultimately reduces the number of CRAH units required. **Table 2** shows the design conditions modeled for the under floor and overhead cabling scenarios. The temperatures for the rack inlet air and the CRAH supply and return air are based on energy balance equations which account for hot and cold air leakage. **In this analysis, the number of CRAH units was reduced from 42 to 31. This leads to an estimated 24% savings in fan and pump power.**

This analysis does not include the benefit of reduced air blockages under the raised floor. Removing abandoned cabling under the floor would have increased the energy savings stated above. In addition to the energy savings, significant capital cost savings are realized by foregoing the cost of 11 extra CRAH units, an estimated savings of $90,000. Finally, the analysis assumed the same chilled water supply temperature for both scenarios. In cases where the chiller is dedicated to the data center, the chilled water temperature could be increased thereby further increasing chiller efficiency and overall savings.

Table 2

Summary of analysis results

	Under floor	Overhead
Rack inlet air	18.3°C	20.0°C
CRAH supply air	17.7°C	19.4°C
CRAH return air	23.0°C	29.6°C
CRAH delta T	5.3°C (9°F)	10.2°C
Number of CRAH units	42	31
Fan power consumption	160kW	118kW
Pump power consumption	20kW	19kW
Total power consumption	180kW	137kW
% power savings	24%	

Modular cable trays

Even overhead cabling can develop the problem of cable "spaghetti" – huge bunch of cables, tangled with each other. When this occurs, new cable cannot be laid because it is impossible to pull out "dead" cable from the pile of existing cables. Cable trays begin to sag under the weight of cables, and this increases the risk of a fault in equipment operation.

For example, consider a row of racks full of servers and networking equipment. Cables connected to panels and servers are laid on top of the racks in trays. When a contact breaks, the connection between two points is lost. When this happens, it is impossible to find or remove the faulty cable because it difficult to locate the defective cable within the mass of tangled cables. In these cases, new cable is often laid between the two points, but the old, defective cable is left inside. Over the course of time, this cable clutter results in 80% of dead cables being left in place, while the total quantity of cables increases.

Gradually, cable tray supports cannot carry the increasing load and more supports must be installed. In addition, no space is left under the ceiling because of the fact that cable bundles are all laid on one level.

The solution to this dilemma is to organize cable in trays which are mounted at different levels (see **Figures 3** and **4**). Multi-level cable tray organization allows data center personnel to sort and plan cable location, integration, and removal on an ongoing basis. If a "dead" cable needs to be removed, it will not be tangled or buried. It will be easy to extract the cable from a single small bundle.

As the data center changes, equipment moves in and out, and new components are added. These changes result in frequent modifications to cables. Therefore it is important that the cable tray system be designed to accommodate such changes. New tray infrastructure must be compatible and interchangeable with the old system. The overhead tray system has to be flexible enough to transform without any fundamental changes in the original system.

Figure 3

Modular cable trays allow for layered placement of cables which allows for simpler cable maintenance

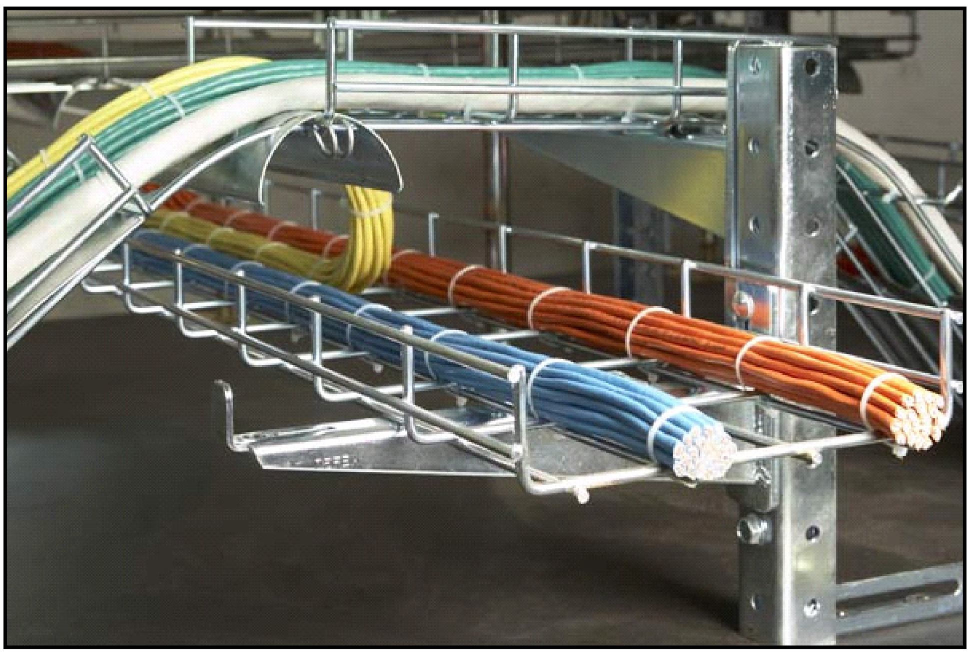


Figure 4

Example of multi-level cable tray

Conclusion

Significant energy waste occurs in data centers when cable congestion forms air dams beneath the raised floor and cable penetrations in the raised floor tiles allow the cold air to escape and mix with the hot air. Modeling and analysis show that the decision to place network data and power cabling to overhead cable trays can lower cooling fan and pump power consumption by 24%.

It is possible to run cables overhead thereby saving energy and improving reliability through improved cable maintenance practices. Running structured cabling and power cabling in overhead cable trays results in several benefits. Raised floor plenums have less impedance to air flow if they are free of cables, less air leakage would occurs because the raised floor would have no holes designed to accommodate cabling. As a result less fan energy would be required to cool servers. The decision to place cables overhead also provides one less reason to absorb the significant expense of a raised floor.

Overhead cable tray technology has made advances in recent years. These systems are now modular and much more flexible in order to accommodate dynamic data center environments. Sound cable practices include the deployment of multi-layered overhead cable tray systems.

About the author

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