Infrastructure

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Contents

1 Infrastructure requirements

Important reminder!

- This section is very much an introductory tour of issues to consider when provisioning infrastructure and software to support our data architecture.
- Many of the themes covered here would warrant an entire 12-week module for themselves!
- Basic awareness avoids costly pitfalls.

2 Server hardware

2.1 Operating system

Will need to decide what OS the server is to run.

Linux and UNIX are generally good choices for data-intensive workloads.

Considerations

- Standard choice for MySQL, PostgreSQL, Oracle, MongoDB, others.
- Straightforward remote access (SSH)

- Different to developer environment (usually Windows)

Windows OS more suited for .net and/or MS SQL Server workloads.

2.2 Specifications

Specify based on expected workload:

Components

CPU based on CPU utilisation using `top`, `htop`.

RAM based on RAM utilisation under expected load:

- Use `free -mh`

Disk space based on disk utilisation (projected or actual):

- Use `df -h` for system disk usage
- Single database:
  `SELECT pg_size_pretty(pg_database_size('Database Name'));`
- Interactive for all databases: `\l+`

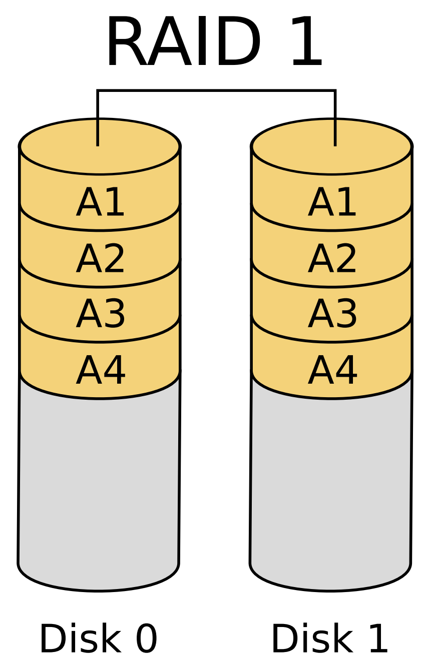
2.3 RAID

Redundant Array of Inexpensive Disks (RAID) uses a number of disks in a raid set such that loss of one (or sometimes more) disks will not cause data loss.

RAID can be done in the operating system software or in hardware.

2.3.1 RAID-1 (Mirror)

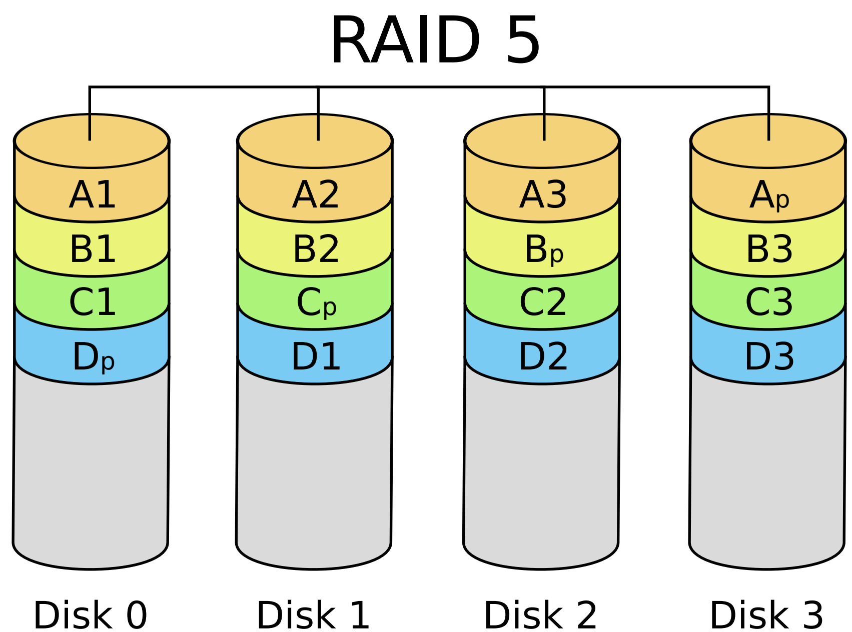
RAID-1 duplicates information on usually 2 disks.



Can tolerate failure and replacement of either disk without data loss.

2.3.2 RAID-5

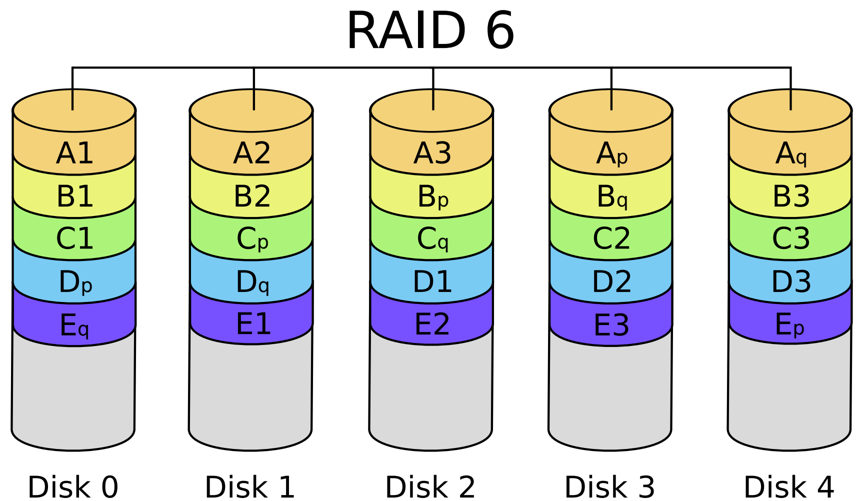
RAID-5 stripes data and redundant *parity* information across 3 or more disks.



Can tolerate failure and replacement of 1 disk without data loss.

2.3.3 RAID-6

RAID-6 stripes data and redundant *parity* information across 4 or more disks.



Can tolerate failure and replacement of 2 disks without data loss.

3 Data centre environment

In office environment such as under a desk, on a filing cabinet etc.

On-site server room possibly as part of larger campus:

- Varying levels of data centre infrastructure provision.

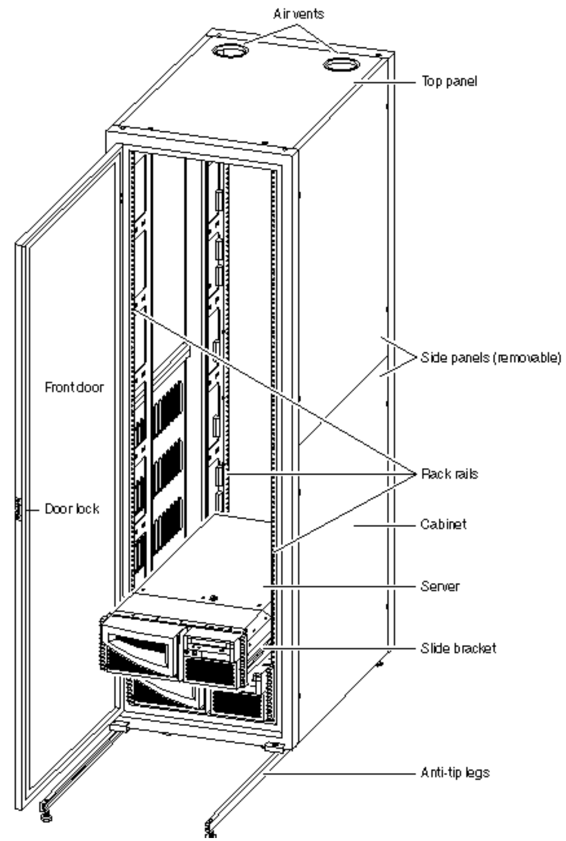
3.1 Co-location

Co-location means that you / your employer bring your hardware to a dedicated data centre faciliity (a co-lo):

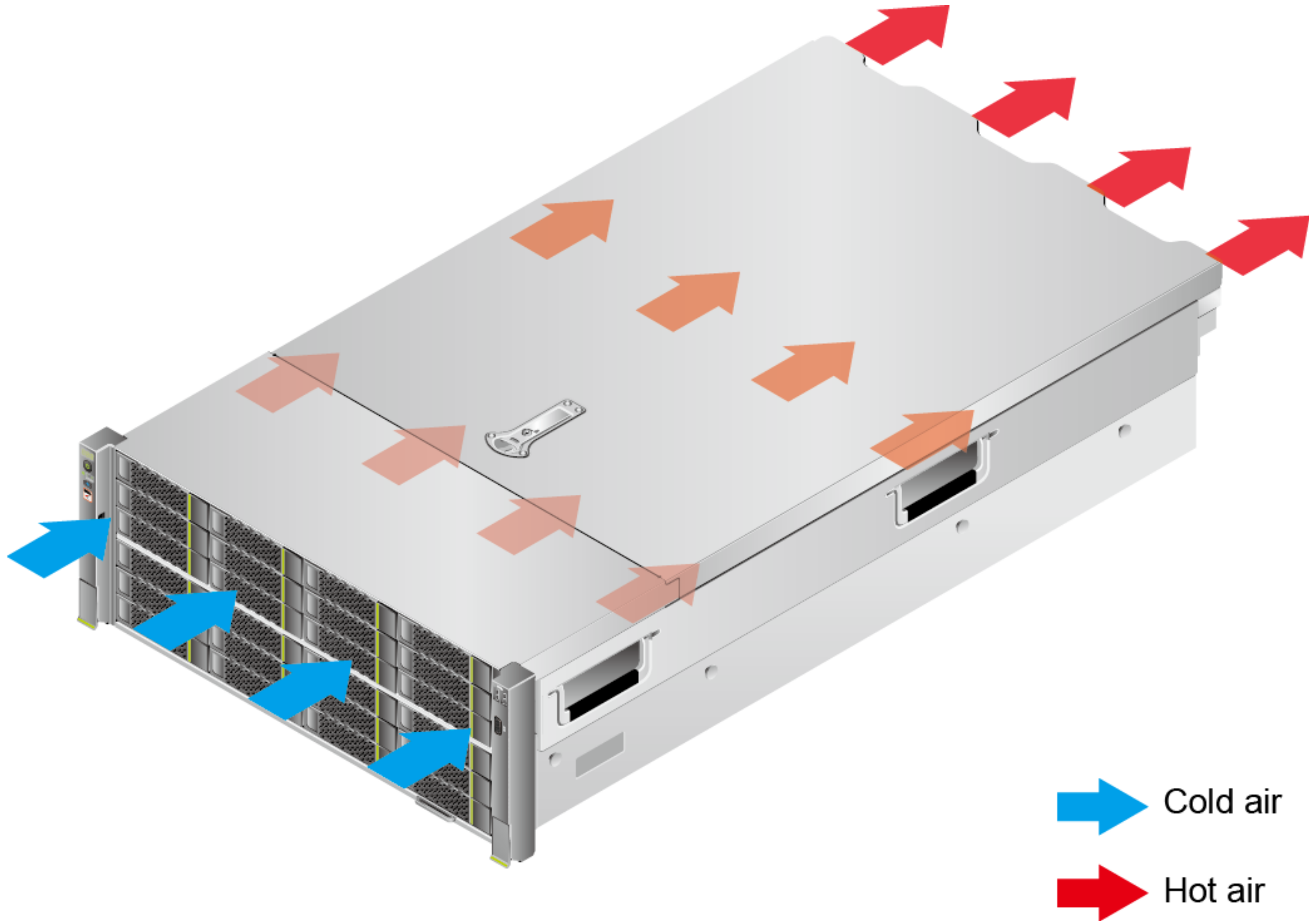
- Can rent individual rack space(s), full cabinet or entire suite / room.
- Power supply may be included or separately chargeable
- Normally have choices of connectivity (separately charged)
- May have on-site remote support available for a fee.

3.2 Racking

Standard rack width is 19 inches with 1.75 inch height per unit



3.2.1 Rack airflow direction



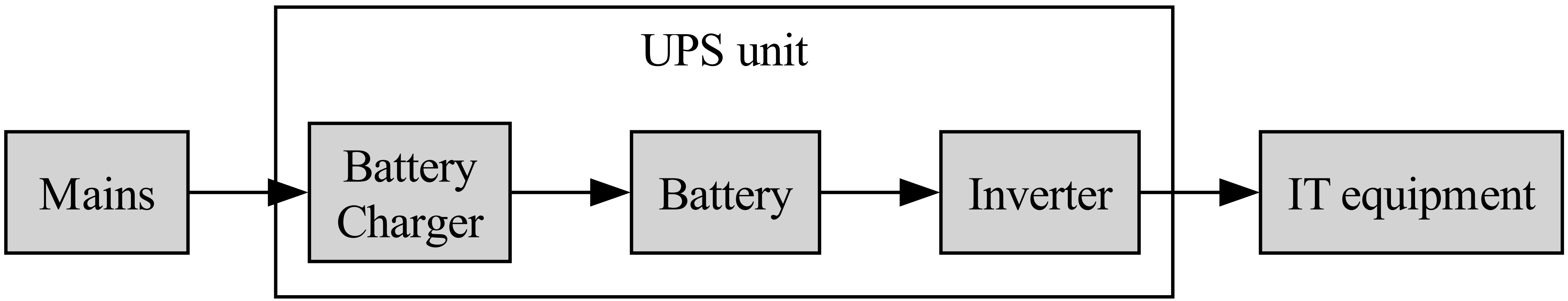
4 Power

Servers and other IT equipment require mains power to operate.

Interruptions or disturbances in the power supply may affect service availability.

4.1 Uninterruptible Power Supplies

Uninterruptible Power Supply (UPS) equipment ensures that a host is protected from short-term power outages and glitches in the power supply.



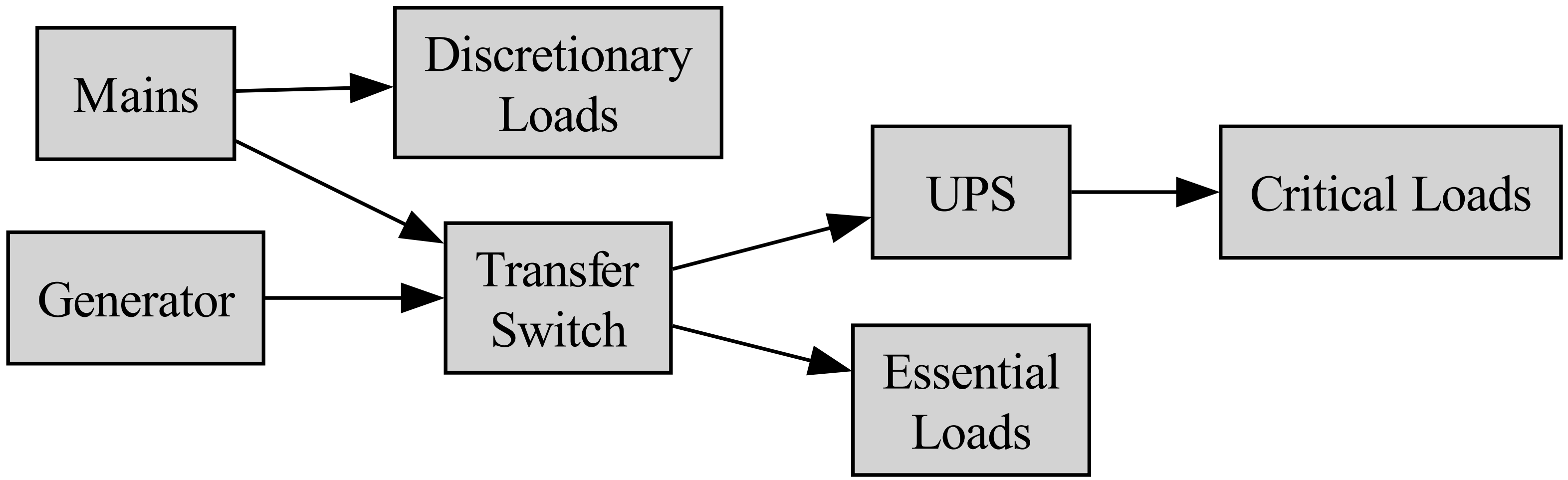
Normal conditions can correct minor power glitches

Short outages can power hosts from battery

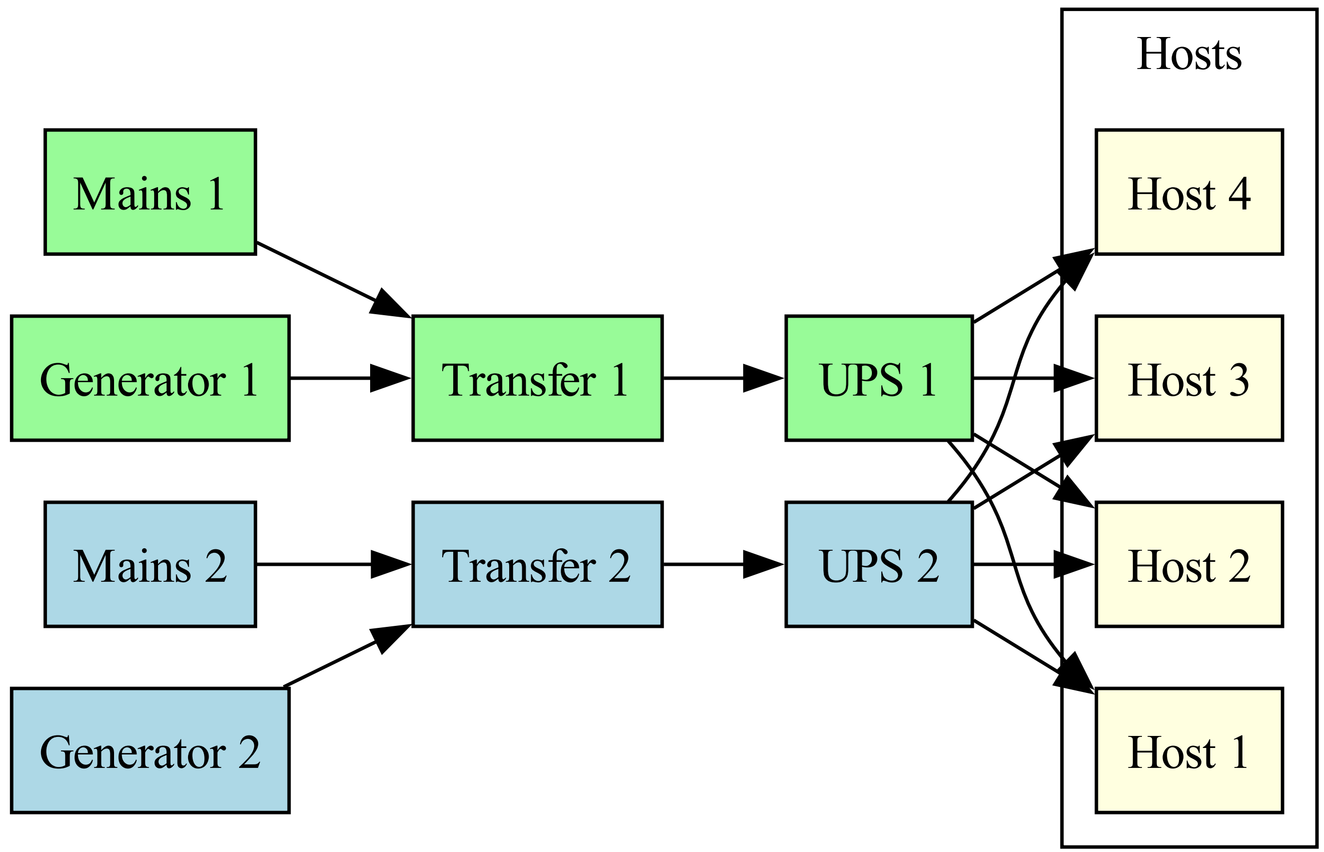
Longer outages can signal hosts to safely shut down

4.2 Generators

Generators can be used to extend run-time during power loss.



4.3 Redundant power paths



5 Connectivity

Host requires connection to a network

Options

- Directly on the internet with a Public IP address.
- On an internal network with a private IP address.
- Internal network but has a NAT public IP address.
- Internal network with a VPN for remote users.

Meet-Me Room (MMR)

Co-location data centres usually have a Meet-Me Room (MMR):

- Internet Providers termination here
- Cross-connected to customer rack

6 Cooling

Heat removal is necessary for all data centre environments.

Where does the heat come from?

- Almost all the electrical power input to IT equipment is converted to heat.
- Without any means to remove heat, the temperature in the closed space will rise quickly.

6.1 Temperature

Temperature numerically quantifies how hot something is

The most common conversion is to/from Fahrenheit.

$$T_C = \frac{T_F - 32}{1.8} \tag{1}$$

$$\Rightarrow T_F = T_C \times 1.8 + 32 \tag{2}$$

The Kelvin scale is rarely encountered in applied settings but is directly related to the Celsius scale:

$$T_C = T_K - 273 \tag{3}$$

$$T_K = T_C + 273 \tag{4}$$

Temperature Scales

Fahrenheit	Celsius	Kelvin	
212	100	373	Boiling point of water at sea-level
194	90	363	
176	80	353	
158	70	343	
140	60	333	
122	50	323	
104	40	313	
86	30	303	
68	20	293	Average room temperature
50	10	283	
32	0	273	Melting (freezing) point of ice (water) at sea-level
14	-10	263	
-4	-20	253	
-22	-30	243	
-40	-40	233	
-58	-50	223	
-76	-60	213	
-94	-70	203	
-112	-80	193	-89°C (-129 °F) Lowest recorded temperature. Vostok, Antarctica July, 1983
-130	-90	183	
-148	-100	173	

Reference: Ahrens (1994)

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University of Illinois at Urbana-Champaign

Table 1: Temperature Scales (Ahrens 1994)

6.2 Thermal envelope

Equipment and humans can only tolerate a certain range of temperatures, or thermal envelope.

Outside thermal envelope

CPU throttling: reducing speed to reduce heat output

Thermal shutdown causing host to become unavailable

Reduced lifespan due to thermal stress

American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE) recommend thermal envelope is between 18 and 27 degrees.

6.3 Cooling methods

In order to keep the temperature and relative humidity within permitted limits, we must rely on some method of cooling.

Options

Conduction uses the room's surfaces to remove heat to the surrounding building.

Passive ventilation involves vents placed appropriately within the room to permit hot air to flow naturally out, to be replaced by cooler incoming air.

Fan-assist ventilation works similarly to passive ventilation, but the air movement is assisted by a fan.

Dedicated cooling is where the room air is not ventilated, but instead heat is removed from it.

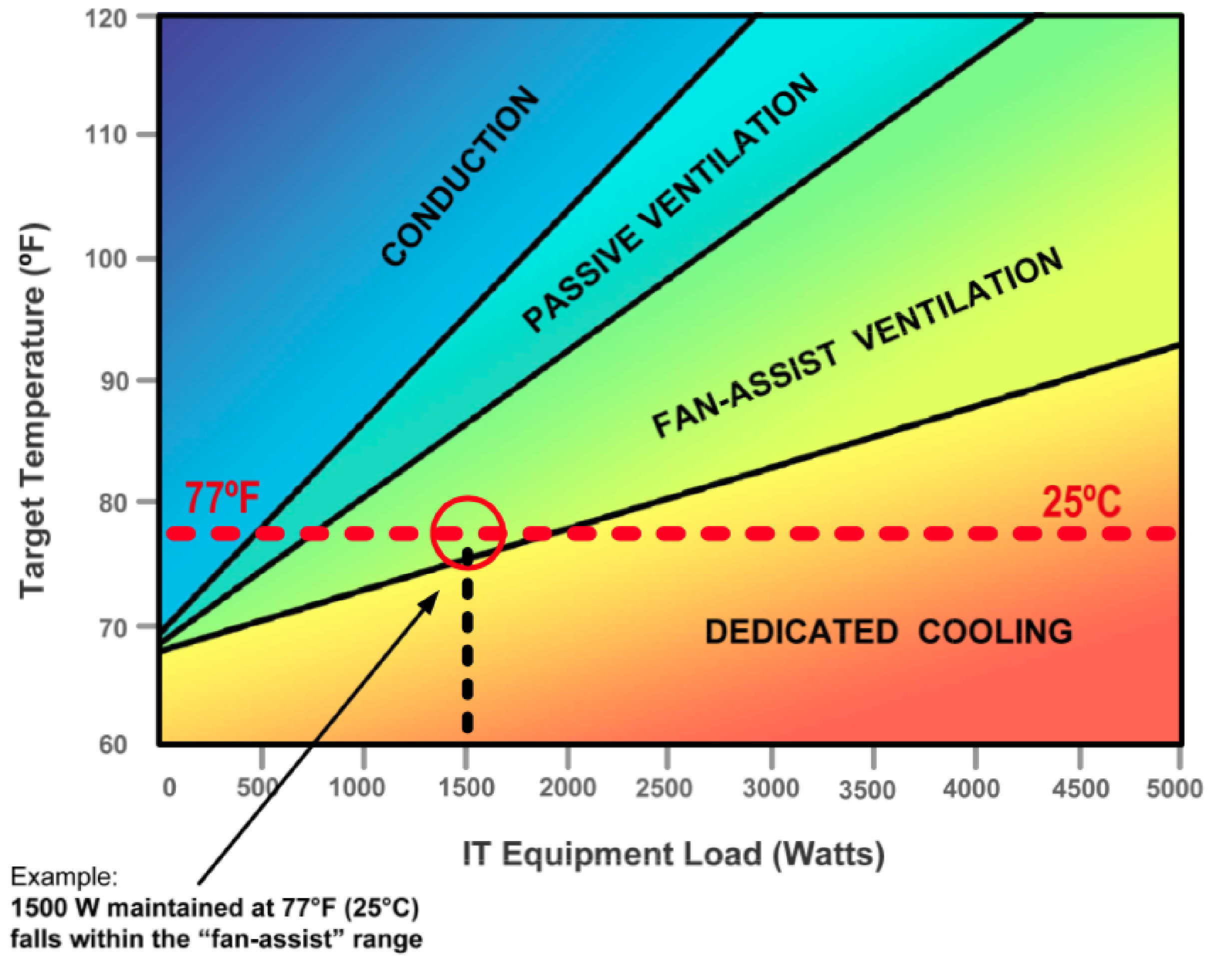


Figure 1: Cooling methods (APC)

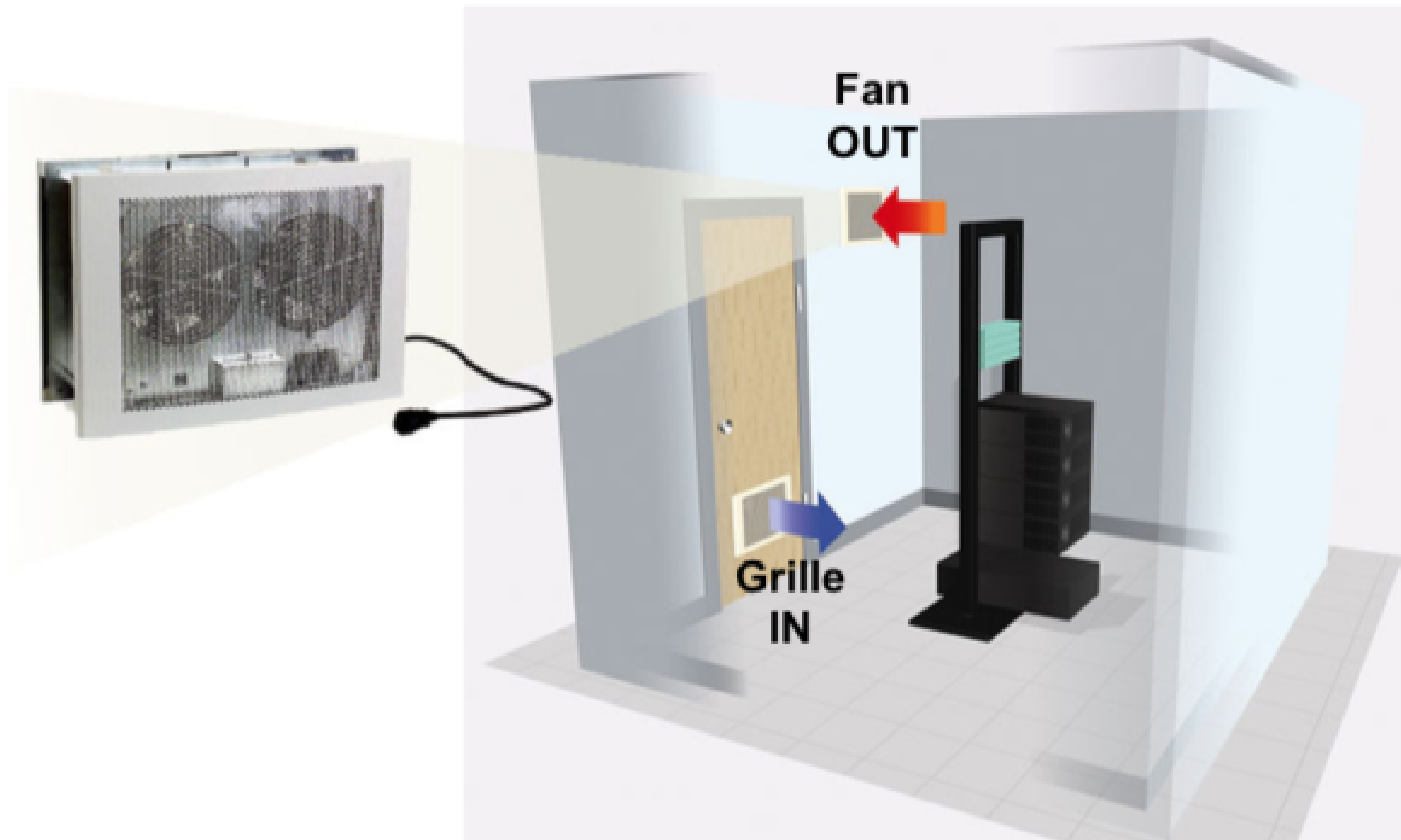
6.4 Fan-assisted ventilation

Fans can be used on in smaller data centre environments to keep the temperature under control by exchanging the air with the ambient / outside environment.

- Fans can be thermostatically controlled.
- Can be powered from a UPS to ensure the fans run even when mains power fails.

Limitations

- In practical terms, anything more than a simple closet with a few devices will need refrigerated cooling.
- Conduction, passive ventilation and fan-assisted cooling schemes are ultimately limited by the outdoor temperature.
- Consider trying to keep a room at 22C when the outdoor temperature is 34C!


Fan
OUT
Grille
IN

6.5 Refrigeration cycle

Refrigeration cycle stages

1. Cold liquid refrigerant in the **evaporator** is warmed by air passing over it, and boils at roughly 7.8 ℃. The air passing over the evaporator gives up some of its heat energy. It leaves at a cooler temperature than it entered at.

2. The **compressor** increases the pressure of the gaseous refrigerant, greatly increasing its temperature to over 50 ℃. In doing so, it also acts as a pump for the refrigerant around the loop, which is carrying the heat energy to reject.

3. Hot gaseous refrigerant enters the **condenser** coil, across which is circulated outside air. As the refrigerant is hotter than the outside air, it gives up its heat to the outside air. The air passing over the condenser receives heat energy from the hot refrigerant, leaving at a warmer temperature than it entered at. The refrigerant is cooled below its boiling point and changes phase to a liquid. It will still be quite hot to the touch!

4. The warm liquid flows through the **expansion valve**, which limits the flow of refrigerant such that it is boiled off in the evaporator. When the refrigerant emerges from the expansion valve, it expands since the flow is limited, and is ready for another cycle in the evaporator.

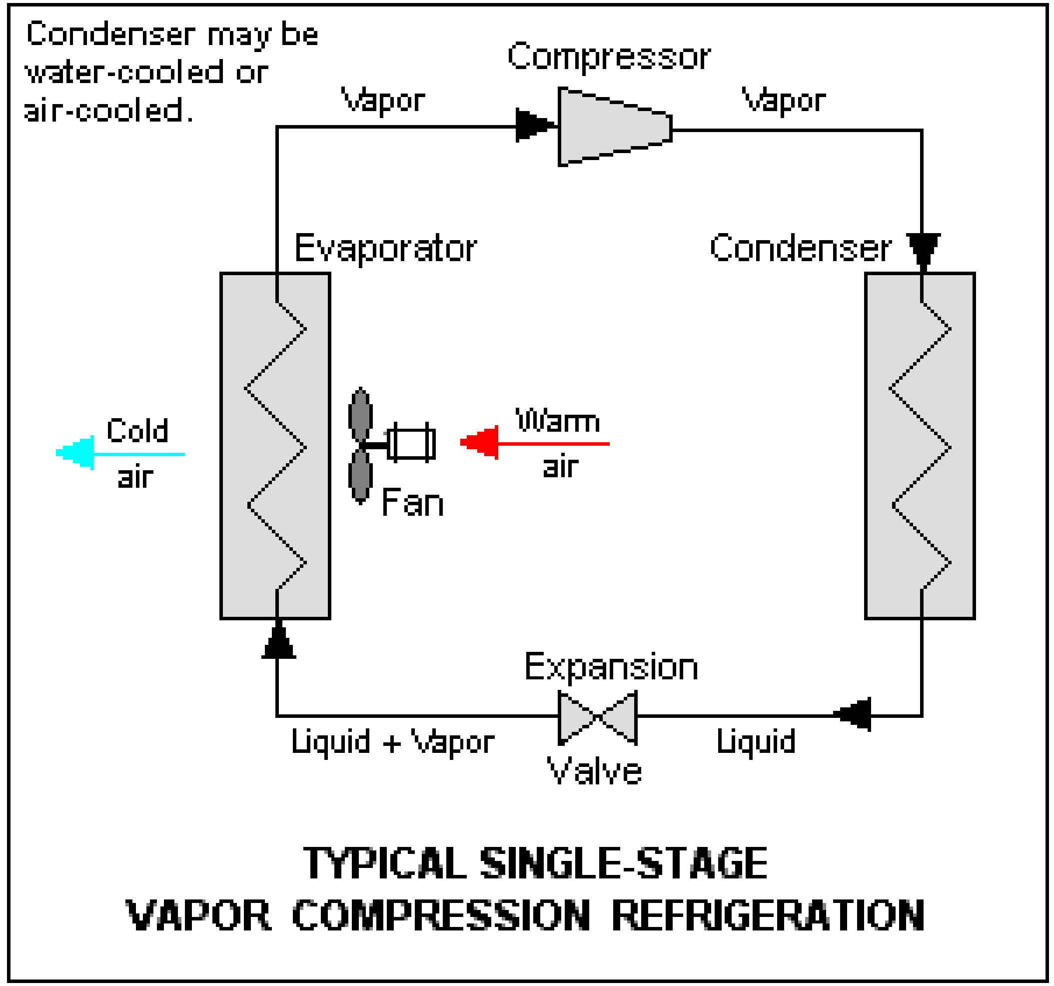


Figure 2: Refrigeration cycle

6.6 Computer Room Air Conditioners

- Warm **return air** enters the CRAC via an opening on the top of the unit. Sometimes the return air is ducted to the unit from above the ceiling.
- Cold **supply air** leaves the CRAC via an opening in the bottom:
  - If there is a raised floor, the cold air is blown out the bottom of the unit under the raised floor. It flows under the raised floor and exits through perforated tiles.
  - In the case of a solid floor, the cold air normally leaves via a large grille on the bottom of the unit.

Other configurations include upflow (reverse of the above, but only on a solid floor), horizontal and other configurations. Cooling units are sometimes located in other areas and ducted to the data centre environment.

Figure 3: Computer Room Air Conditioner

6.6.1 Airflow

For the cooling system to work properly, we **must use a hot aisle / cold aisle arrangement**. Where a raised floor is used, the perforated tiles must be in the cold aisle, and not in the hot aisle.

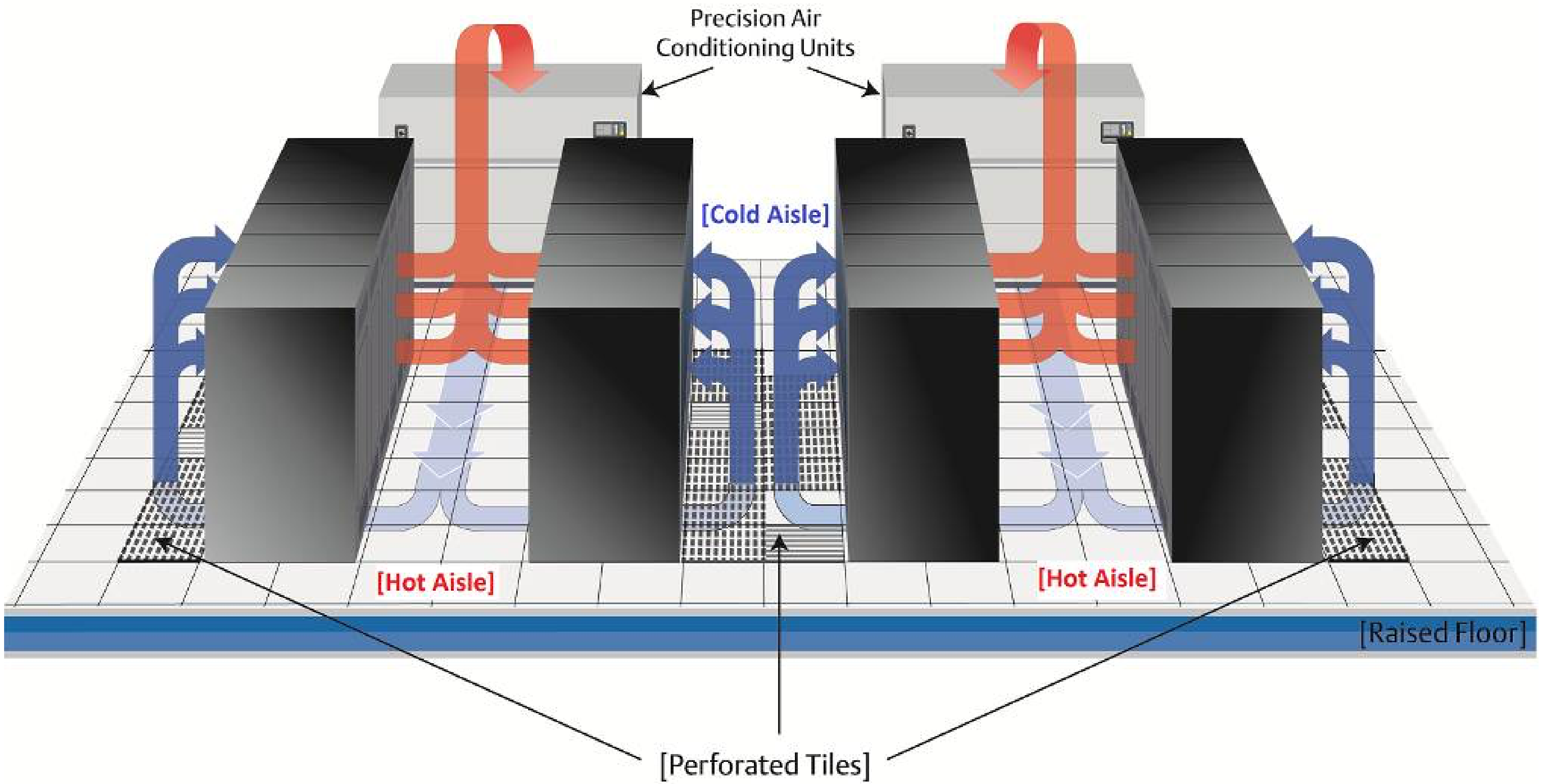


Figure 4: Airflow from Downflow CRAC through raised floor

6.6.2 Self-contained air-cooled DX

Self-contained units have all refrigeration components within the CRAC's casing, Figure 5.

The condenser supply and exhaust are ducted from the outdoors.

Usage

- Limited in cooling capacity to approx 15 kW due to unit size and ducting
- Often seen in small on-site server rooms.

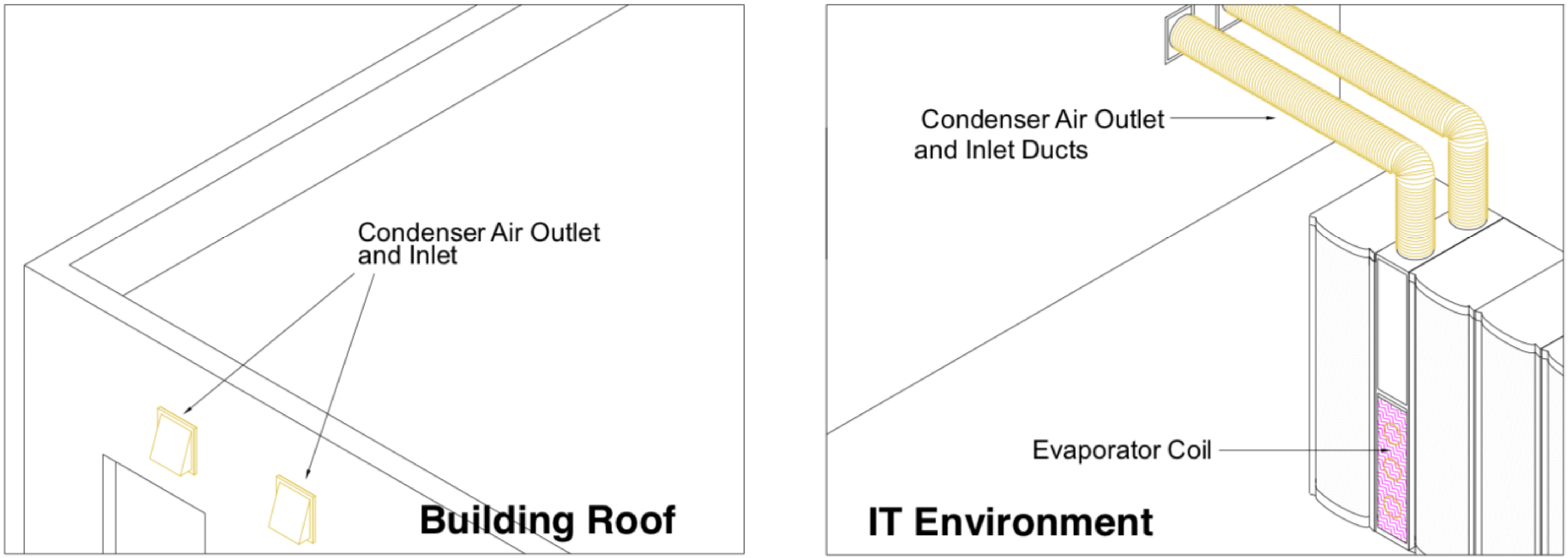


Figure 5: DX self-contained CRAC (APC)

6.6.3 Air-Cooled DX

Direct expansion, often abbreviated DX, cooling systems house the evaporator, compressor and expansion valve within the CRAC unit. The condenser is sited externally, with wiring and refrigerant connections from the CRAC unit, Figure 6.

Usage

- Candidate for 7 kW to 200 kW.
- Multiple units often used for larger capacities and to provide redundancy (see later).

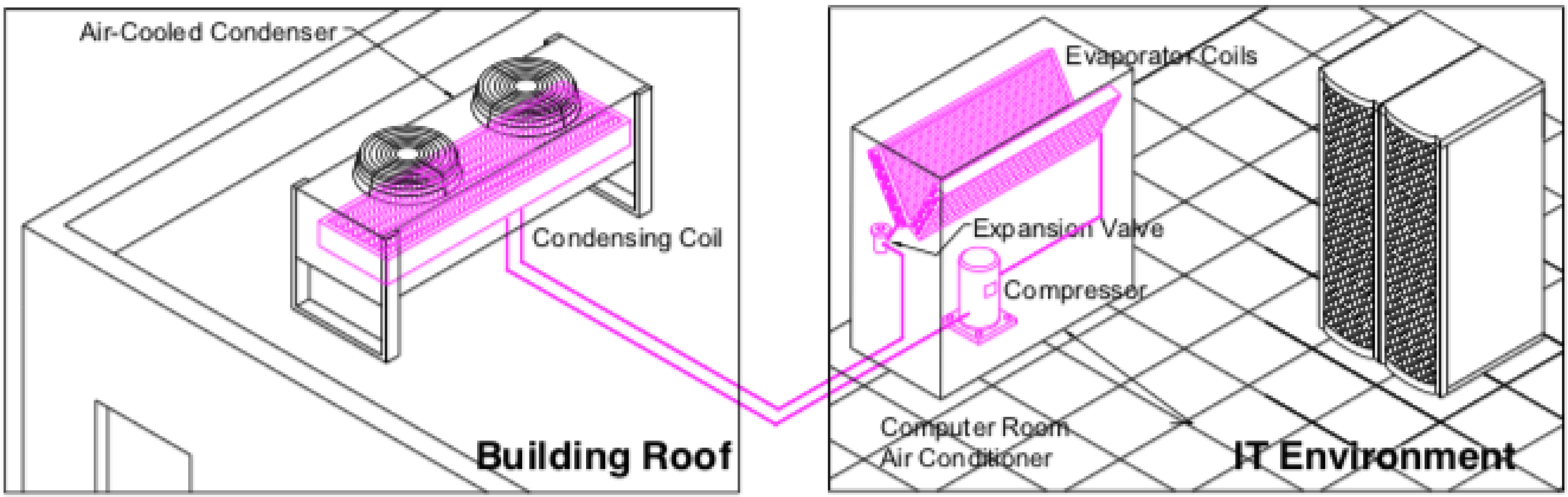


Figure 6: DX air-cooled CRAC with condenser (APC)

Figure 7: Condenser

6.6.4 Chilled water cooling systems

Chilled water cooling systems involve the supply of chilled water to Computer Room Air Handlers (CRAH) in the data centre environment.

The chilled water is produced in a separate *chiller*.

The chiller rejects heat from the chilled water loop to the atmosphere in similar ways to DX CRACs:

Normally large number of CRAHs served by a small number of chillers and cooling towers.

Chilled water systems also can incorporate large buffer tanks for load balancing, energy price optimisation and to provide *ride through* in case of power failure.

In a multi-tenant building, the landlord will often supply chilled water as a metered chargeable service to tenants.

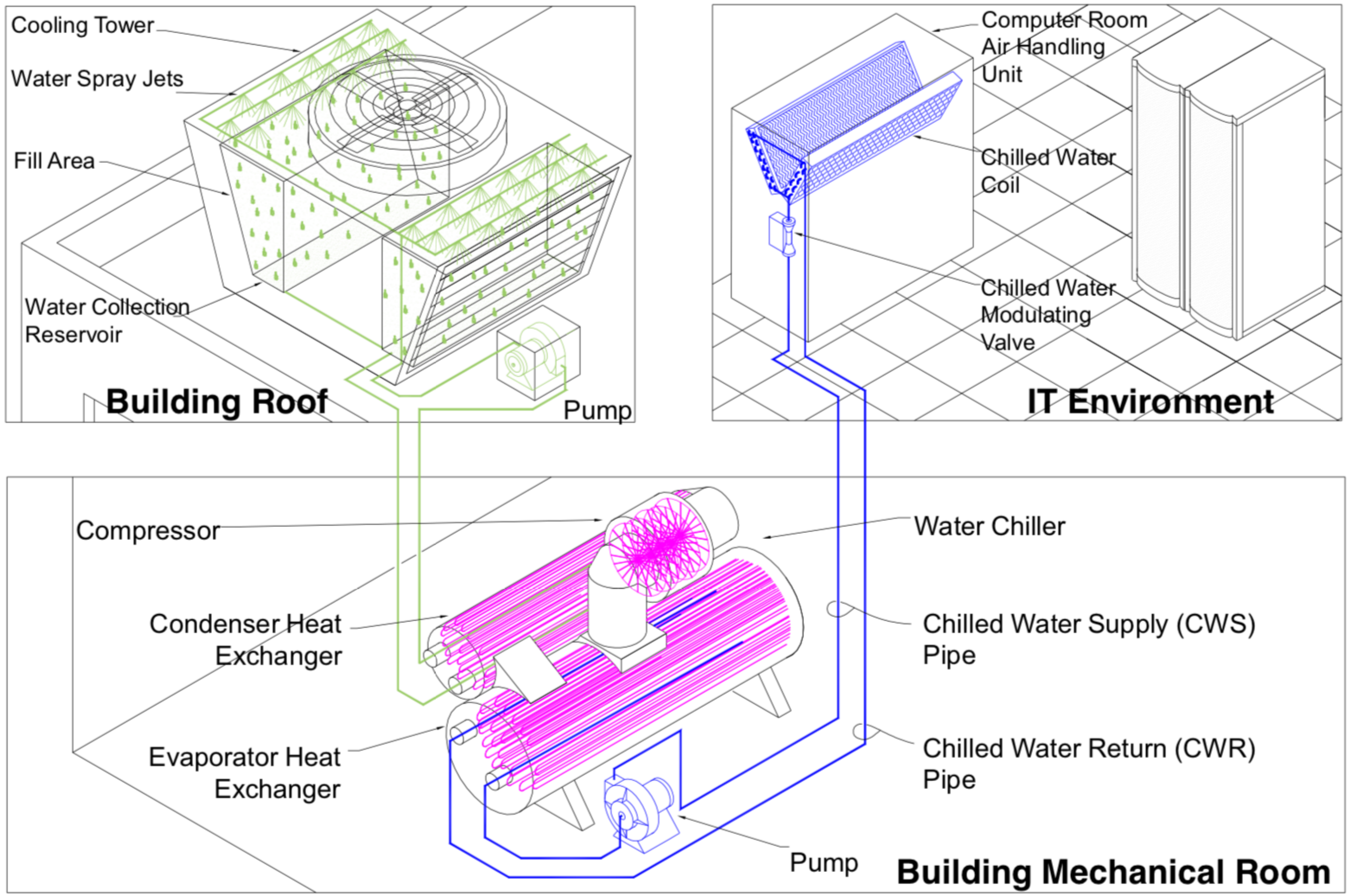


Figure 8: Chilled water system