White Paper –

Wireless Sensor Network for Rack and Room Monitoring

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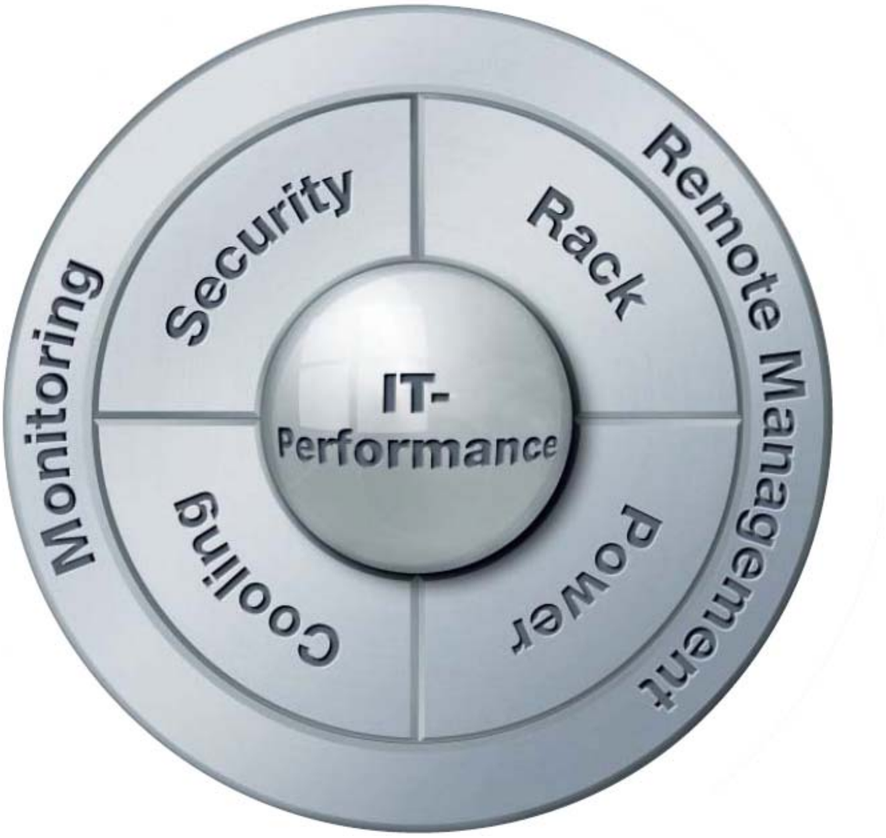

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List of Abbreviations

AM	-	Amplitude Modulation
CMC-TC	-	Computer Multi Control - Top Concept
CSS	-	Chirp Spread Spectrum
dB	-	Decibel
DDL	-	Dispersive Delay Line
FM	-	Frequency Modulation
ISM band	-	Industrial, Scientific and Medical Band
IT	-	Information Technology
I/O unit	-	Input/Output unit
LCP	-	Liquid Cooling Package
mA	-	Milliampere (0.001 A)
MDMA	-	Multi Dimensional Multiple Access
Mhz	-	Megahertz
PM	-	Phase Modulation
WLAN	-	Wireless Local Area Network
µA	-	Microampere (0.000001 A)

Executive Summary

Today, sensors are used to monitor the data centre. They measure various environmental conditions in the data centres and transmit the data to a central location. As the cabling of the sensors entails significant costs and effort, Rittal offers a wireless system that eliminates the need to lay cables. The special “chirp” technology makes the system secure and efficient, saving costs and labour in the overall balance.

First, however, it must be examined as to whether deployment of the wireless system is sensible or even possible at all with regard to the spatial conditions. Placement of each individual sensor must also be verified prior to commissioning. However, the outlay entailed by this verification can be reduced to a minimum by using a measurement system sensor.

The wireless version of the sensor network enables comprehensive monitoring of server racks and IT rooms and does not add so many additional components that serviceability of the existing systems is impaired. Simple operation and flexibility make the system user-friendly and efficient; a sound basis for the data centre of the future.

Introduction

Today, data centres constitute the IT nucleus of virtually every medium to large-sized company. Although invisible to most employees, this is where all of a company's relevant information flows together. Only in the event of a data centre failure do many people become aware – in an unpleasant manner – of the importance of this facility.
Reliability is not only demanded of the actual IT equipment – such as servers, storage units, switches, etc. – but also of the infrastructure of the data centre. For this, Rittal offers the RimatriX5 concept – a modularly structured complete solution for data centres, consisting of rack, power, cooling, monitoring & remote management and security components.
Part of the security aspect concerns the rack and room monitoring by means of measurement sensors. Sensors for temperature, humidity, smoke or access control are available, among others.
Different systems have been utilised for this for many years, including the modular Rittal CMC-TC (**C**omputer **M**ulti **C**ontrol - **T**op **C**oncept) system. In the established solutions, the available sensors are then hooked up to the central unit by cable connection.
In a growing and evolving data centre environment, however, it is sometimes difficult or even impossible to establish a cable connection between the I/O unit and sensor. Similar problems also arise in industrial environments, such as in assembly plants or workshops, for example. A sensor network can provide valuable data here as well – but the cabling of the sensors causes difficulties. The solution to this cabling dilemma is a robust wireless link between the base unit and the sensors.

Objective and requirement

The data centre must be monitored around the clock in order to avoid possible failures and prevent these as early as possible. The sensors that monitor the environment report changes and warn if values approach critical ranges. This enables early intervention, thus preventing the failure of technical equipment. The placement of temperature sensors allows for the monitoring of temperature variations in the data centre. This allows heat accumulation, i.e. hotspots, to be localised and avoided by means of appropriate measures. A direct increase in cooling efficiency is the result.

As the positioning of the sensors often leads to cabling problems, Rittal offers a solution utilising wireless sensors that are linked by radio with the control station. The retrofitting of additional sensors entails little effort and the repositioning of sensors can be performed easily and quickly during running operation.

An interference-free wireless link must be established between the sensors and the receiver (wireless I/O unit) for optimum data transmission. The proper positioning and technology guarantee an optimal quality of connection in order to ensure uninterrupted data transmission and monitoring.

The sensors must be placed within range of the wireless I/O unit. The quality of reception can be improved through an external aerial or repeater. Signal strength decreases as the distance between a sensor and the wireless I/O unit increases. Obstructions such as walls, other server racks, etc. additionally suppress the signal strength. Metallic objects in particular have a stronger influence on the reception than other objects.

The wireless connection should transmit all communicated data in a minimum of time across the longest possible distance without any data being interfered with by other wireless connections or, conversely, interfering with other wireless connections. Additional requirements are low costs and low energy consumption.

The wireless CMC-TC technology from Rittal offers the optimal solution with regard to the quality of wireless communications, costs and security.

The chirp technology-based wireless link completely utilises the potential bandwidth, thus guaranteeing a high volume of data during transmission. It is also robustly safeguarded against other interfering radio signals and requires very little energy. Parallel operation with WLAN installations is possible without any problems.

Transmission system

In today's wireless systems, attention must be paid to various features that, taken together, should result in a secure, effective and energy-saving solution. Primary among these are the transmission quality, transmitted data volume and the low energy consumption to minimise costs.
Rittal utilises chirp transmission for this purpose. "Chirp" refers to a signal whose frequency can be varied in terms of time, although the amplitude still remains constant in this for a brief period (or over a certain distance).
In wireless transmission, signals are modulated and transmitted to the receiver via a carrier frequency. This is typically handled using one of three different forms of modulation.
The first technique, **A**mplitude **M**odulation (AM), is highly susceptible to interference. The second technique, **F**requency **M**odulation (FM), reduces this susceptibility but requires almost twice as much bandwidth as amplitude modulation. The third technique, **P**hase **M**odulation (PM), became quite popular with the advent of the digital age. Phase modulation significantly reduces the required bandwidth compared with frequency modulation, yet also combats interference and fluctuations of the carrier frequency.
MDMA (**M**ulti **D**imensional **M**ultiple **A**ccess) combines the advantages of all three modulation techniques. It is utilised for the entire transmission – from the sensor to the processing unit – and presents the best solution for uncorrupted transmission of information and effective transport: an extensive range with low transmission power. Information transmission in the baseband ideally takes place by means of sync impulses, which have the shortest possible impulse intervals with a specified bandwidth that is not to be exceeded. These can be easily generated in the transmitter and easily detected in the receiver.
By contrast, transmission via the air interface makes use of chirp impulses. These make full use of the available bandwidth B and are thus less susceptible to interference during transmission.

Although both signal forms appear to be different in the time span, they still cover the same spectrum:

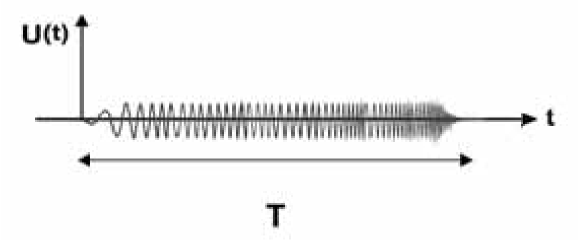

Figure 1: The frequency of a chirp impulse in a specified time span T [1]

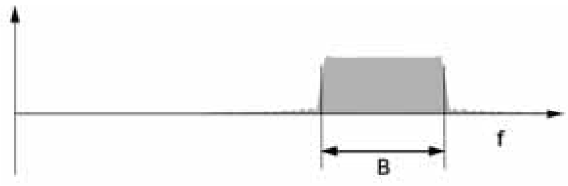

Figure 2: The output spectrum (bandwidth B) of a chirp impulse in the frequency range [1]

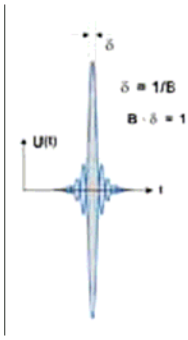

Figure 3: The frequency of a sync impulse in the time span [1]

Figure 4: The output spectrum (bandwidth B) of a sync impulse in the frequency range [1]

With a **D**ispersive **D**elay **L**ine (DDL) – a filter which, with the help of interference, only relays signals of certain bandwidths while at the same time also modifying their frequency – it is possible to transform them from one form to the other.

Thus, transmission throughout the entire system is performed at the air interface with interference-free frequency modulation. By contrast, processing is handled in the equipment itself with slightly demodulated impulses which have a narrow bandwidth.

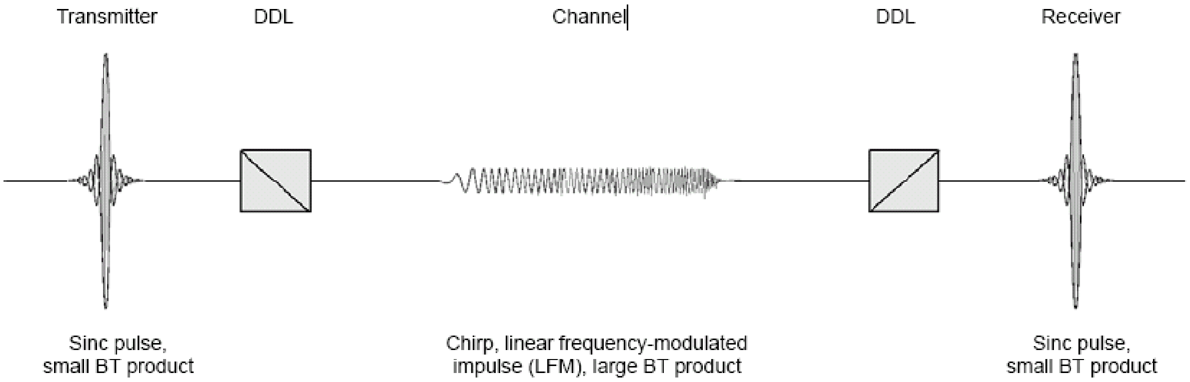

Figure 5: MDMA transmission [1]

Altogether, MDMA transmission provides optimised utilisation of the assigned channel capacity; it is an economical system that minimises the usage of expensive and energy-intensive digital technology at high data transfer rates.

[1] Source: Nanotron Technologies GmbH; White Paper: “nanoNET Chirp Based Wireless Networks”

Wireless sensor transmission technology

The **C**hirp **S**pread **S**pectrum (CSS) method, a simplified version of MDMA, is used for wireless sensors from Rittal. CSS was especially designed for the requirements of sensor networks with mid-range data transfer rates. It is particularly well suited for battery-operated systems as the supply current is only 1μA in sleep mode. Approximately 45 mA are required when receiving data, and between 85 mA and 300 mA for transmission.
CSS operates at 2.4 gigahertz in the licence-free ISM band and reaches a maximum data transfer rate of 2 Mbit/s. With the CSS version in use, the ranges extend to 200 m outdoors and 50 m inside buildings, attaining data transfer rates of up to 1 Mbit/s. Each character is transmitted with a chirp impulse with a bandwidth of 80 Mhz and a fixed impulse interval of one microsecond. The charge and discharge of the impulse reduces the bandwidth; rapid charge and discharge means more efficient utilisation of the bandwidth. This efficiency is stated as being the roll-off factor. Here $\alpha = 0$ corresponds to complete utilisation of the bandwidth, and $\alpha = 1$ the most disadvantageous possibility.
With Rittal's wireless technology, the roll-off factor is $\alpha = 0.25$, which results in an effective bandwidth of 64 MHz. The system gain is 17 dB. The signals are extremely insusceptible to narrow band interference and are even somewhat resistant to broadband interference. In addition, CSS is relatively insusceptible to radio echo (multipath reception) as all energy proportions, spread across a bandwidth of 80 Mhz, are collected. This allows the required transmission capacity, and hence the exposure due to electromagnetic radiation, to be reduced.
Utilising CSS not only saves energy and costs but also significantly reduces electromagnetic radiation as well. [2]

[2] Source: Nanotron Technologies GmbH; White Paper: “nanoNET Chirp Based Wireless Networks”

Installation

Placement of the wireless I/O unit and sensors

The following should be considered when planning sensor placement:
In contrast to infrared and light wave beams, a radio signal can penetrate ceilings, walls and other objects. Ideally, a signal spreads out evenly out in the open and generates a spherical field.
As the distance from the transmitter increases, the signal strength decays; objects located between the transmitter and receiver also dampen the signal. Therefore, the range is shorter in buildings than out in the open. It should also be noted that other obstructions (e.g. persons) can present themselves intermittently. If possible, the signal should be directed orthogonally through obstructions and niches should be avoided.

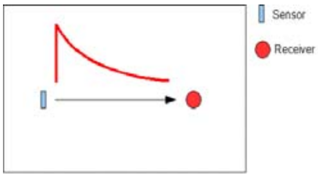

Figure 7: Signal strength with increasing distance between the transmitter and receiver

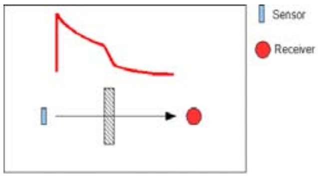

Figure 6: Signal strength with increasing distance and additional obstruction

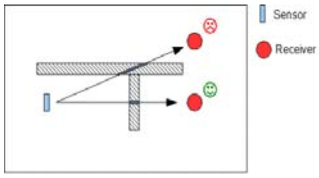

Figure 8: Comparison of the reception quality of orthogonal and non-orthogonal penetration

Metallic objects lead to a weakening of the signals, resulting in a “radio shadow”. The reception quality is very poor or there is possibly no reception at all in this radio shadow. When installing internal receiving aerials in bayed enclosures with glass doors, the installation location should not be on the same enclosure side as that of the transmitter but instead on the opposite side.

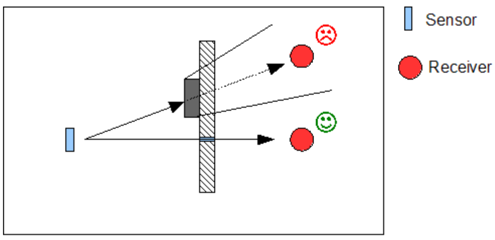

Figure 10: Radio shadow originating from a metal part

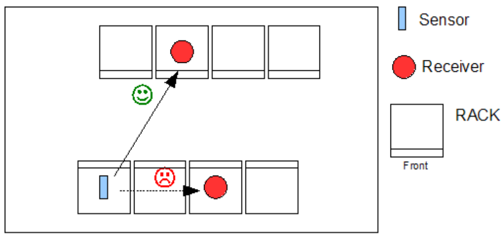

Figure 9: Placement of the receiver in bayed enclosures

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If the wireless I/O unit has been mounted in a shielded area and the reception by the standard aerial on top of the enclosure is problematic, an external aerial can be used. The ideal installation location is a central place in proximity to the sensors to be detected. The aerial should also be directed parallel to the sensors' installation location.
Another possibility for extending the range of reception of the wireless I/O unit is to use repeaters, which can relay a signal. Radio shadow can be eliminated in this way and sensors can be placed far away from the I/O unit.

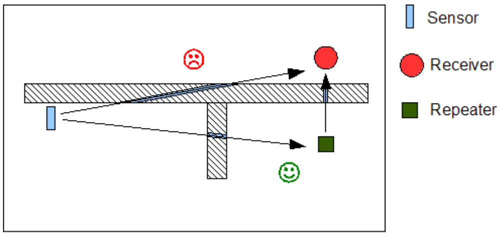

Figure 12: Improved reception through signal redirection via a repeater

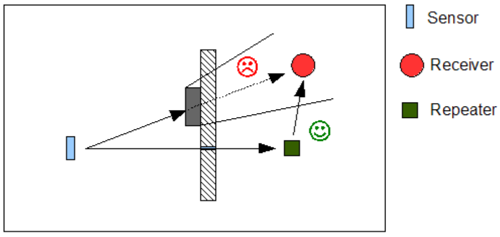

Figure 11: No more radio shadow after signal redirection via a repeater

Setting up

Setting up a wireless sensor network is accomplished through plug & play installation.
By means of a simple commissioning procedure, consisting of a programming mode and programming button, the sensors are programmed to the wireless I/O unit through plug & play. Once programmed, the sensors only have to be confirmed by the Processing Unit II; they then start to transmit the initial measurement data.
Programming of the sensors should be performed prior to the actual installation. The distance between the I/O unit and sensor must not exceed 5 metres during the programming phase as the wireless I/O unit only operates with reduced transmission power during this phase. Brief blinking by the sensor and I/O unit confirms that a connection has been successfully established.
In addition, the wireless measuring system must be programmed. This measurement system can measure the radio transmission quality between the installation location of a sensor and the wireless I/O unit. Simple installation and direct comparisons are made possible through use of an identical design, such as that of the sensors. An examination performed with the aid of the measurement system must first be performed for the initial installation or, if problems occur, during operational radio communication. If the measurement system shows that the selected location is suitable, then the sensor can be installed there.
The sensor ranges of the wireless I/O unit and the performance reserves for communication can be increased by using repeaters. Another alternative for improving the transmission power is to connect an external aerial. If a wireless I/O unit is mounted inside an enclosure, the aerial can be placed externally. This prevents the enclosure walls from attenuating the signal.
Once the measurement sensors have been programmed to the wireless I/O unit, the entire system can also be relocated to a different location at a moment's notice. If the I/O unit is separated from Processing Unit II, the sensors still remain programmed. The sensors do not have to be

reprogrammed if they are reconnected to the same or a different Processing Unit II; they are ready for operation immediately.

If a sensor is no longer needed or another wireless I/O unit is to be connected, it can easily be reset to the factory settings. In this mode, it is disconnected from the wireless I/O unit and can be programmed to another one.

In the modular CMC system, the processing unit forms the central administration and configuration unit and can be configured via Telnet or a website. The threshold values for warning and alarm messages, among other things, can be specified there. It is also possible to configure whether a message should be sent via e-mail or SMS in the event of an alarm.

Measurement values can be recorded and settings changed using various programmes from Rittal, such as the "CMC-TC Manager".

Thus, password-protected access to processing unit II is ensured throughout the network. This makes it possible to obtain an overview of the current status or glance at the most recent messages. [3]

[3] Source: Rittal GmbH

Sample application

Temperature measurement in the data centre

Temperature measurements are performed in a data centre on two server rack suites, each one comprising eleven racks. The temperature sensors have been placed on two racks at the start of the rack suites, and two racks have been placed in the middle of the rack suites. Each rack has been equipped with four sensors; two on the cold aisle side, two on the warm aisle side. One sensor each is placed towards the bottom and towards the top of the enclosure.

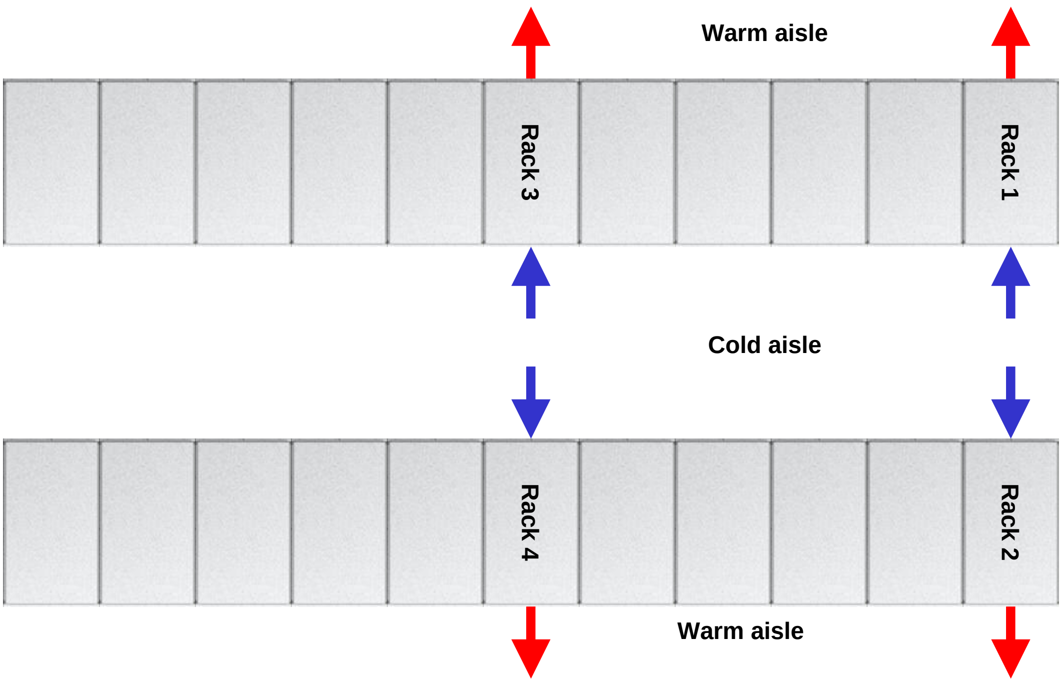

Figure 13: Top view of the rack suites

With labelling of the 4 equipped racks
and indication of the airflow direction

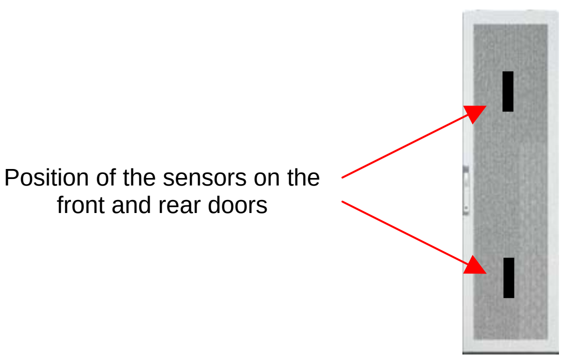

Figure 14: Positioning of the sensors on the doors

Wireless sensors are used because this measurement is not performed for the purpose of permanent monitoring but for temporary monitoring of the temperature. In this way, the awkward and expensive laying of cables can be dispensed with.
Analysis of the measurement data has revealed that the racks at the start of the enclosure suites have significantly higher cold air intake temperatures and thus exhibit warm air exhaust temperatures; a clear temperature differential between top and bottom was also detected.

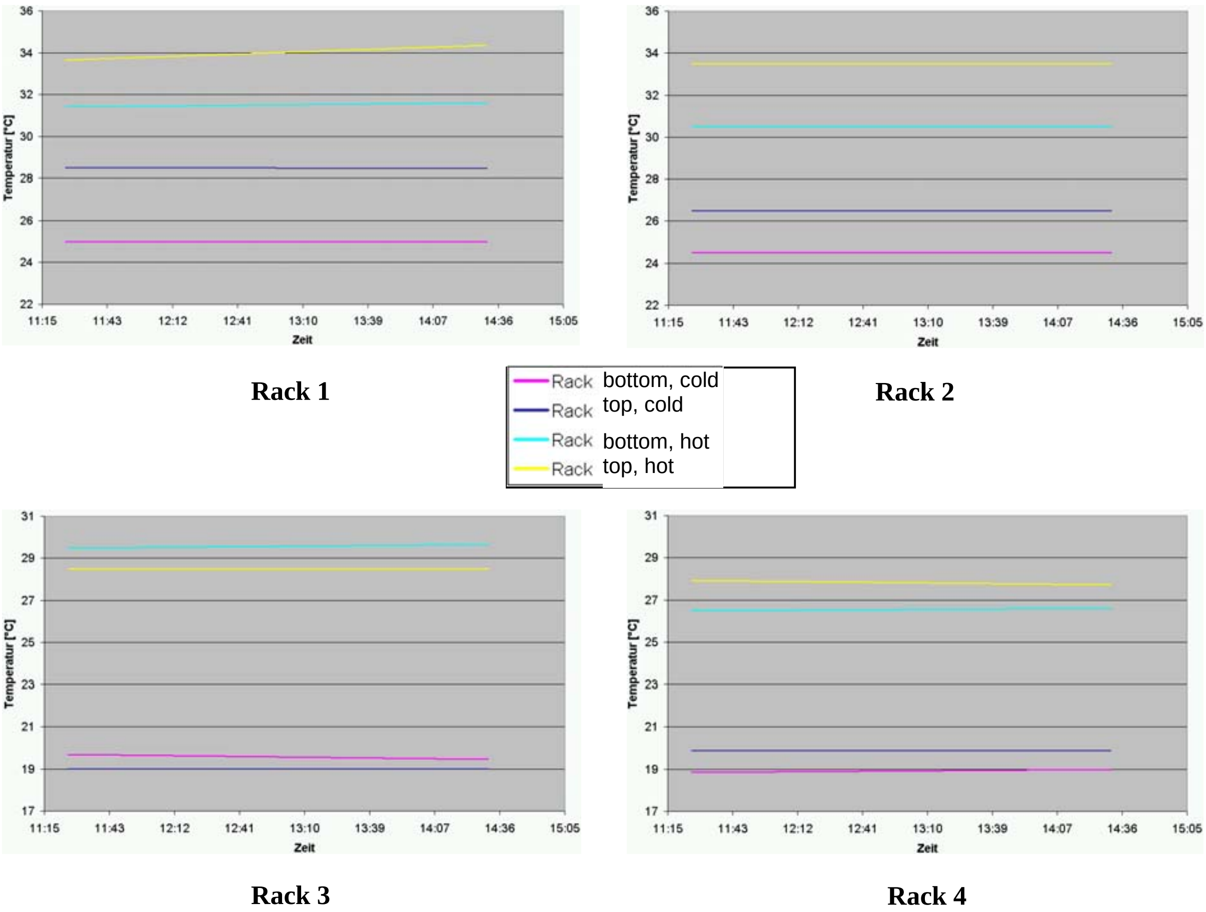

Figure 15: Measured temperatures at the doors of the 4racks [4]

[4] Source: Rittal GmbH; measurement performed by Martin Dörrich (PM SK-IT) at Host Europe, Cologne, Germany

The reason for this is recirculation of the warm air from the warm aisle. When utilisation of the data centre reaches the limits of its cooling capability, this temperature will increase again.
Installing a cold aisle containment system can prevent this. This also has a positive effect on the temperature differential, so that all enclosures can be supplied from top to bottom with cold air of a uniform temperature.

Summary:

The measurement revealed problematic areas in the cooling of the data centre. It was possible to minimise these by installing a cold aisle containment system. This resulted in greater cooling efficiency and an increase in the capacity limit of the data centre.
This in turn resulted not only in cost savings but also reduced the susceptibility of the data centre to overheating while achieving greater energy efficiency for cooling.

Cost comparison of CMC-TC with cable connections and wireless

Data centre setup

In order to prevent failure due to overheating, each rack in a data centre should be monitored by a temperature sensor.

Here is a layout plan of the data centre with the racks:

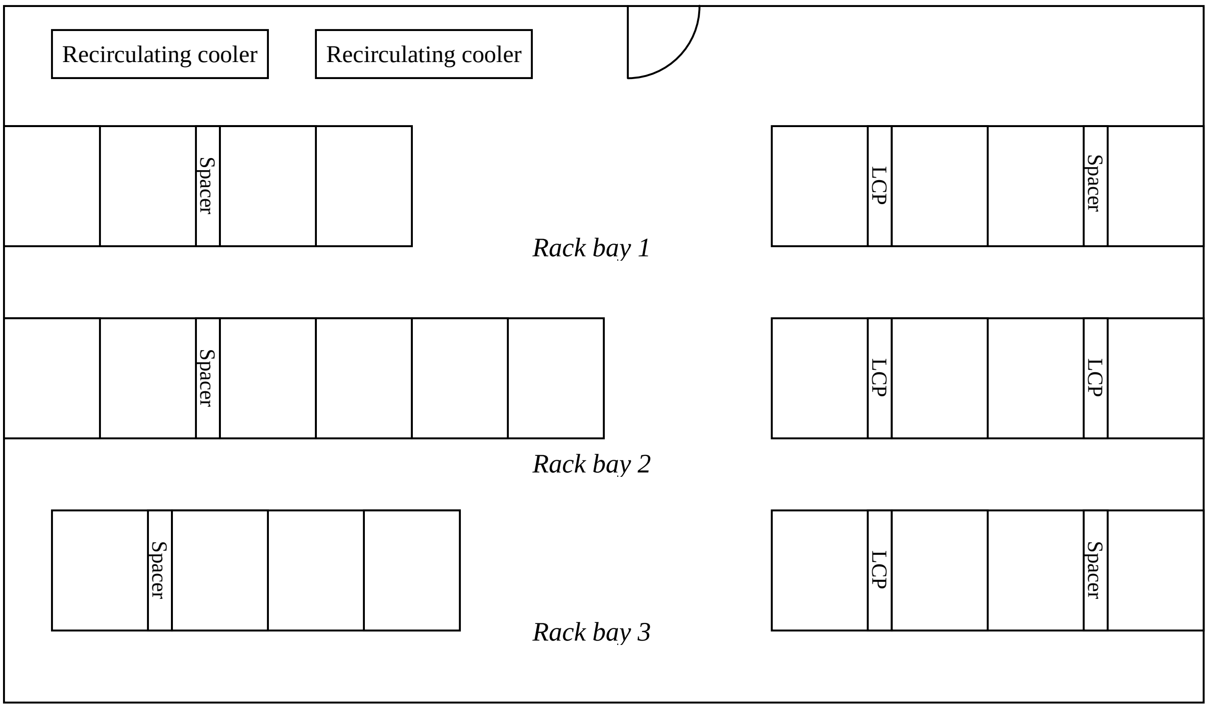

Figure 16: Layout plan of the data centre

Rack bay 1: 8 server racks; 1 LCP; 2 LCP spacer
Rack bay 2: 6 network racks; 4 server racks; 2 LCPs; 1 LCP spacer
Rack bay 3: 8 server racks; 1 LCP; 2 LCP spacer

Altogether, 26 racks are each to be equipped with a temperature sensor and the recirculating coolers are to be monitored with a digital input. A total of 26 temperature sensors and 2 digital inputs are required in addition to Processing Unit II, the I/O unit and the necessary accessories. It is possible to deploy the standard sensor model here with a cable connection between the sensor and I/O unit. Alternatively, it is possible to use the wireless sensor version from Rittal. This does not have a cable connection between the sensor and I/O unit. Instead, the data are transmitted by means of a wireless link.

Cost comparison

In order to decide which option to take, the costs should be considered: [5]

Order no.	Designation	Pack	Sales price	Req. units, standard	Req. units, wireless	Standard costs	Wireless costs
7.200.210	Connection cable D/F/B	1	€7.20	2	1	€14.40	€7.20
7.200.221	Programming cable	1	€23.60	1	1	€23.60	€23.60
7.320.100	Processing Unit II	1	€382.00	2	1	€764.00	€382.00
7.320.210	I/O unit	1	€158.60	7	0	€1,110.20	€0.00
7.320.240	Wireless I/O unit / repeater	1	€340.00	0	2	€0.00	€680.00
7.320.241	WL external aerial	1	€63.60	0	2	€0.00	€127.20
7.320.242	WL measurement system	1	€105.00	0	1	€0.00	€105.00
7.320.425	24V power pack, 100-230V AC input	1	€52.50	2	1	105,00 €	€52.50
7.320.440	1 U mounting unit	1	€28.50	3	2	85,50 €	€57.00
7.320.441	Single cover	2	€13.20	0	2	€0.00	€26.40
7.320.470	Sensor unit connection cable, 0.5 m	4	€11.00	1	1	€11.00	€11.00
7.320.485	Sensor unit connection cable, 15 m	1	€16.30	3	1	€48.90	€16.30
7.200.450	RJ12 extension cable for 5 m sensors	4	€33.00	20	0	€660.00	€0.00
7.320.500	Temperature sensor	1	€18.60	26	0	€483.60	€0.00
7.320.505	WL temperature sensor	1	€95.40	0	26	€0.00	€2,480.40
7.320.580	Digital input	1	€15.30	2	0	€30.60	€0.00
7.320.585	WL digital input	1	€106.00	0	2	€0.00	€212.00
					Totals	**€3,336.80**	**€4,180.60**

Estimated additional expense for cabling, commissioning, setup	€2,500.00	€1,000.00
Totals with cabling	**€5,836.80**	**€5,180.60**

Included in cabling are the following:

- Work on the wall/floor (laying of cable conduits, replastering, etc.)
- Tools
- Materials (plaster, seals, etc.)
- Extension cables

The I/O units must be connected with a Processing Unit II for the versions with a cable connection. In addition there are the cable connections between the 28 sensors and one each of the I/O units. As the sensors are distributed throughout the entire room and their cabling requires a lot of time and effort, costs for the cabling, commissioning and setup can be estimated at roughly €2,500.

In the wireless version, Processing Unit II and a wireless I/O unit are installed on the left side, a wireless I/O unit on the right side. As a result, one wireless I/O unit is positioned centrally for all sensors on the left side and the other one centrally for all sensors on the right side.

The external aerial is installed on the rack in question. Therefore, only one cable connection has to be laid between the second wireless I/O unit and Processing Unit II, and the costs can be estimated at approximately €1,000.

What has not been accounted for, however, is that operation is restricted at times while cable is being laid, a process which may take several hours or even days!

[5] Source: Rittal GmbH

Conclusion

The acquisition costs for the wireless version are greater than for a cable-linked sensor system due to the higher prices for the wireless sensors. However, the wireless sensors can be used immediately after the I/O unit has been programmed. In the cable-linked version, the cable connections still have to be laid first and this is more expensive and time-consuming. The different environmental requirements play a major role in the costs for the cabling. Expenditure on cabling fluctuates depending on the conditions. The installation costs therefore vary from project to project as well. In unfavourable situations, the costs for cabling can even be as high as the acquisition costs themselves.
If the acquisition and installation costs of both versions are considered in this case, the overall costs for the wireless version are lower. Moreover, the fact that only limited operation is possible during cable laying must be taken into consideration, resulting in additional costs for commissioning. Although sensor batteries must be replaced every 5 years, expenditure on this is quite minimal in comparison with laying cable.
This shows that the wireless version is not only easier to install and requires less space, but is also more economical in terms of the overall cost calculation.

Summary

Even given the current state of technology, electronic components are still susceptible to failure due to water, heat or other factors. Failure of a data centre translates into substantial costs for a company and can subsequently result in various problems and costs. In the near future as well there will be no effective antidote against these vulnerabilities, which is why data centres have to be permanently monitored.

A very good and sensible solution is offered by the wireless monitoring system from Rittal. Its simple plug & play installation enables rapid setup, as well as simple and clear operation. The chirp technology makes the system secure, efficient and environmentally friendly to boot, thanks to its low power consumption and the reduced electromagnetic emissions.

Although the acquisition costs for this wireless system are higher than for the cable-linked version, expenditures for the setup and installation are, of course, cheaper. The system is more flexible and more quickly deployable in the event of a new installation, as the normal operations of a data centre are scarcely impacted during the installation.

Thus, the CMC wireless system from Rittal offers a reliable alternative to conventional cable-linked sensors in many situations. Existing CMC installations can also be easily supplemented with the wireless components. This underscores the great advantage of the modular CMC-TC system.