White Paper

BACnet and EnOcean enable Energy Efficient Buildings

Integration of batteryless wireless sensors offers amazingly new opportunities for BACnet building automation

When it comes to choosing a facility's backbone for carrying building-automation information, wired BACnet bus systems have become a norm. However, wireless systems have been growing in popularity since the arrival of energy-autonomous and service free wireless components based on EnOcean technology. Practical experience shows that the two technologies, side-by-side, exhibit advantages that maintain an ideal wired/wireless balance—combining the strengths of both.

By Marc Dugré (Regulvar Inc.), Fabian Freyer (Thermokon Sensortechnik GmbH) and Armin Anders (EnOcean Alliance)

1. Wired and Wireless compared

The following collective assessment of major criteria relevant for the market indicates that neither of the two transmission media, Wired or Wireless, comes out alone on top in a building-automation scenario. For an optimal solution, it takes both; each implemented where it is better than the other.

Features	Wired	Wireless
Range	+ +	-
Installation effort and flexibility	--	+ +
Data volume	+ +	--
Availability of information in room	-	+ +
Reliability	+ +	+
Cost	+	+ +

Table 1: Features of wired and wireless transmission media

1.1 Range

If you want to transmit data over long stretches in a building (more than 30 meters, for instance) there is no economical alternative to a wired bus. An obvious example is the transmission of sensor and actuator information across many floors from a central point. For communication between buildings, long distances, and for very large amounts of data, fiber optic networks are a good option. But signal transmission within the same floor, in a radius up to about 30 meters, is easily handled by the right wireless technology.

In addition to the unique energy harvesting maintenance free wireless solutions from EnOcean, another significant differentiator that sets EnOcean above other potential wireless choices is the use of sub-gigahertz frequencies: 868 MHz in Europe and the Middle East, and 315 MHz in the USA and the Far East. These frequencies are in contrast to wireless systems like those based upon 802.15.4 RF radios, ZigBee and Bluetooth, nestled in the 2.4 GHz band. The lower, more optimal frequencies exhibit lower attenuation through walls and achieve about twice the range for the same transmitting power.

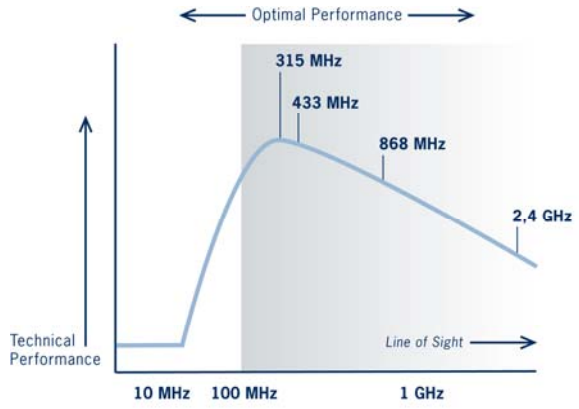

Fig. 1: Transmission loss vs. frequency

Figure 2 illustrates the performance of wireless systems in buildings as a function of their frequency. Frequencies below 250 MHz are unfavorable because of the inefficiency of their antennas, if these are to be made compact enough to match market requirements. On the opposite end, frequencies of 1 GHz and higher suffer increasingly from propagation loss through walls and other obstacles. The ideal range is found between around 300 MHz and 1 GHz, where you find low attenuation and the range needed to make a system economical; i.e., fewer devices per square meter.

1.2 Installation effort and flexibility

When it comes to installation effort, building alterations and subsequent wishes for expansion, the advantages are clearly on the side of wireless technology. Wireless components can be easily fitted, for little cost, even on surfaces inaccessible for wired solutions. Speed and flexibility are advantages not only when expanding and altering at a later date but also during initial planning and final installation; where components' placement can be changed at the last minute—a relatively common occurrence in building operations.

1.3 Data volume

Battery-less and service free wireless sensors are ideal for sending measured data packets and control commands, which in most cases are of small data

volume. These data packets can then be funnelled back to monitoring stations or shared with other devices in different locations via a wired infrastructure, where higher bandwidths are available, where fully isolating routing can be achieved, and where fewer government restrictions are imposed.

1.4 Availability of information

A benefit of using wireless is that the information sent by devices is accessible anywhere in a room or space, not just along the wires. So components can be optimally positioned without concern for existing wires or inaccessibility of places for wiring. Combining a wired BACnet system with EnOcean wireless components allows an installation to benefit from both technologies.

Fig. 2: Window contact

Fig. 3: Bidirectional wireless room sensor

1.5 Reliability

The reliability of wired BACnet bus systems has been widely proven. However, when it comes to wireless systems, some people are still sceptical, but many feel increasingly confident since the advent of EnOcean wireless. After all, there are already over 100,000 buildings benefiting from the advantages of EnOcean wireless technology. Installations include corporate headquarters (e.g. SAP, IBM, Bosch, Siemens, Nestlé), public buildings (schools, hospitals, government facilities), historical buildings, residences, landmarks, retails, industrial and hotels.

EnOcean nodes avoid the 2.4 GHz band of Bluetooth and WLAN. Devices in that range have to share a limited number of channels. The more popular this band becomes (the more WLAN-enabled PCs are available), the greater the problems will become through interference with networks and other permanently active systems, such as mobile phones, Bluetooth, and cordless video monitors. Well-founded radio planning is the next building block in the reliability of wireless systems. Here, EnOcean offers professional support of instrumentation tailored to that purpose, as well as planning guidelines long time proven in practice.

How wireless components obtain their energy is a further and major aspect of secure, reliable installation: Reduced range, rather than failure of sensing, is the result of batteries running out of power, which results in having to replace batteries to keep the system functioning as a whole. In the EnOcean technology, the focus is "no batteries; so, no maintenance." The use of freely available, ambient energy - generated by sunlight, motion, heat, or vibration, for instance - is a key benefit of the wide market acceptance of this wireless solution, especially in buildings.

The concerns of building professionals regarding battery-powered wireless sensors are quite justified when you think of the thousands of batteries in a modern building that would need regular replacement. These concerns do not apply to EnOcean sensors. Moreover, data published about the expected, average lifetime of batteries can seldom be taken at face value. Although the use of batteries may initially be more cost-attractive, the service, disposal (toxic waste), and malfunctions can quickly negate the initial savings.

1.6 Cost

Today's wireless systems already offer cost benefits of as much as 15% upon first-time installations (depending on complexity) compared to some wired solutions with the same range of functions. When alterations or expansions are undertaken (statistics show that the average office building is reconfigured about every five years), the cost benefit can go up to 80%.

Tying the EnOcean systems into the BACnet network allows those benefits to increase by extending the physical reach of the data they share.

2. Standards

2.1 The BACnet Standard

BACnet is a manufacturer-independent data communication protocol for Building Automation and Control Networks. Developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), BACnet is an American national standard, a European standard, a

national standard in more than 30 countries, and an ISO global standard. The protocol is supported and maintained by ASHRAE Standing Standard Project Committee 135.

2.2 The EnOcean Standard

The EnOcean Alliance is a consortium of companies working together to further develop and promote self-powered wireless monitoring and control systems for sustainable buildings by formalizing and opening the interoperable wireless standard. The EnOcean Alliance has developed the specification for the interoperability of the sensor profiles for the wireless products operating in license free frequency bands and is currently applying for ratification as an international standard at the IEC technical committee JTC 1/SC 25/WG 1. The EnOcean Alliance is open to anyone and is a manufacturer-independent non-profit organization based in San Ramon, CA.

3. Putting BACnet and EnOcean together

The joint objective of the BACnet Organization and the EnOcean Alliance is: simple but substantial reduction of the energy requirement in buildings. The two technologies match optimally for this purpose: BACnet is the leading wired technology for intelligent building-services management; while the EnOcean standard represents wireless-based automation technology.

For example, self-powered sensors and actuators communicate wirelessly as an intelligent sub-network in a room or area; doing away with conventional cabling precisely where the configuration of the room is most-frequently altered. This also obviates the need for those associated costs. Communication with the control or supervision level can then travel through BACnet gateways, each linking many rooms or intelligent sub-networks to the BACnet backbone of building automation. In this way, the flexibility of a wireless system is ideally combined with the large bandwidth and range of a wired backbone.

The rooms in modern office buildings are rearranged, on average, about every five years; so wireless systems provide just the right flexibility. More and more, interior architects are discovering the new possibilities of design and installation presented by wireless systems, where a switch or sensor is located no longer by where electric wires are located. They can be put in the best place, in ergonomic terms. Switches to control lighting and blinds can be attached simply to each workplace of an open-plan office, for example. Light switches can be adhered to the headboard of a hotel bed, to a mirror, the tiles, or near the shower partition in the bathroom.

Room temperature sensors no longer need to be installed near doors, avoiding corruption of the temperature reading by the opening and closing of a door.

Products enabled by EnOcean reduce the laying of cables inside and outside buildings, allowing the user to place sensors just about anywhere (e.g., on glass, furniture, windows, and ceilings).

4. BACnet interoperability

BACnet ensures interoperability between devices of different manufacturers if all participants in a project agree on certain BACnet interoperability building blocks (BIBBs) defined by the standard. A BIBB defines the services and procedures that have to be supported at the server and client end to implement a particular system requirement. The protocol implementation conformance statement (PICS) accompanying a device lists all supported BIBBs, object types, character sets and options in communication.

5. EnOcean Interoperability

To save transmission energy the EnOcean radio telegrams must be designed to be as short as possible. Because of that, the sensor informs his receiver during the teach-in only about his function and data decoding characteristics. For this purpose the so called "EnOcean Equipment Profile" (EEP) has been agreed within the EnOcean Alliance, a telegram profile number that relates to a look up interpretation table in the receiver.

To enable interoperability of equipment from different manufacturers a standard was defined for the teach-in procedure, for the data communication and for the EEP itself. Up to now the specification was restricted to unidirectional sensor communication (around 50 EEPs), those are currently enhanced to bi-directional sensor communication and bid-directional communication of a gateway with EnOcean wireless actuators.

Byte#	Description
SYNC_BYTE 0	Synchronization Byte (0xA5)
SYNC_BYTE 0	Synchronization Byte (0x5A)
TYPE	Telegram info, e.g. length, Rx/Tx
ORG	Telegram info, e.g. PTM/STM
DB_3	Data byte 3
DB_2	Data byte 2
DB_1	Data byte 1
DB_0	Data byte 0
ID_3	Byte 3 of transmitter ID
ID_2	Byte 2 of transmitter ID
ID_1	Byte 1 of transmitter ID
ID_0	Byte 0 of transmitter ID
STATUS	Status info, e.g. repeater level
CHK	Checksum (LSB)

Table 2: Serial data protocol of an EnOcean radio receiver

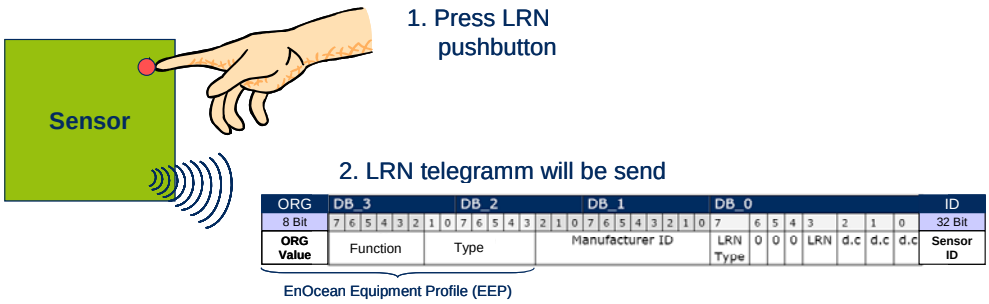

Figure 4: Serial data protocol during tech-in (EEP equipment profile)

6. BACnet/EnOcean Gateway

Today twisted pair is the most important media for BACnet products. This enables a high quality of data transmission and the possibility to supply power to the connected units. Using a gateway is a very simple and already existing solution to combine the power of both worlds: Wired BACnet and Wireless EnOcean. In the following the functions of a BACnet MS/TP RS485 EnOcean wireless receiver is described. Visit www.big-eu.org for further information and definitions on the subject of BACnet.

6.1 Device description

Devices can be connected by a twisted-pair cable (120 Ω line resistance). The maximum number of bus users (without use of a bus repeater) is given by the RS485 transceiver. The protocol used is the international standard BACnet MS/TP. This enables connection to appropriate remote terminals such as an automation station or a building services management system supporting the BACnet MS/TP protocol.

The standard defines the transmission parameters as 8N1, i.e. 8 data bits, no parity, 1 stop bit. The baud rate is freely selectable (9600, 19200, 38400, 57600, 76800, 115200), and is set by DIP switches. It is also possible to set the BACnet MAC address (bus address) of the device. A different bus address is needed for each device.

6.2 Configuration tools

BACnet MS/TP wireless receivers are always operated together with other BACnet automation stations or building services management systems such as BACnet operating workstations. All parameter settings are possible through the BACnet network. Tools from the particular manufacturer of an automation station or building services management system are used to start up a BACnet network.

6.3 BACnet interoperability building blocks

The standard defines interoperability building blocks (BIBBs) enabling BACnet devices to operate together. The different devices can be allocated to these BIBBs, which use different services to communicate with one another. A distinction is made between data and requests:

A	Client
B	Server
DS	Data sharing

DM	Device management
RP	Read property
COV	Change of value

The following BIBBs are implemented:

DS-RP-B	Read property
DS-WP-B	Write property
DS-COVU-B	Send data on change of value
DS-WPM-B	Write multiple properties
DM-DDB-B	Device properties
DM-DOB-B	Address information about objects
DM-DCC-B	Communication control

6.4 BACnet device profile

BACnet defines various profiles that offer and support different services. One of these ready defined types should be used for good interoperability.

The EnOcean BACnet gateway operates with a device profile called BACnet application-specific controller (B-ASC).

6.5 BACnet objects

The gateway has various BACnet objects. Four of these objects serve for the basic setting of the device. The others describe the slots, each interpreting a wireless receiver. A slot is described by 12 objects (six analog inputs, four binary inputs, one binary value, one multistate input).

6.5.1 Objects for basic setting of device

Object name	Object type / instance	Meaning
Thermokon_SRC_BACnet	Device / 100 (default) + MAC address of address switches	Basic settings of the device, e.g. MAX master.
Offset device ID	Analog value 1	This value plus the set MAC (0-127) corresponds to the device ID (writeable 0-4194200) after write, reset and new initialize.
EnOcean teach-in	Analog value 2	The set value selects the

COV mode	Multistate value 1	next slot to be teached in, after which it is automatically reset to 0. This setting is for COV mode. The following modes are supported: - Off - Local broadcast - Global broadcast

6.5.2 Objects in each slot in not teached-in state

The instance numbers of a slot always start on round hundreds, e.g. slot 1 on 100, slot 2 on 200, through slot 32 on 3200.

Object name	Object type / instance	Meaning
Sensor01_DataByte_0	Analog input 100	Interpreted data of EnOcean data byte 0 with analog information.
Sensor01_DataByte_1	Analog input 101	Interpreted data of EnOcean data byte 1 with analog information.
Sensor01_DataByte_2	Analog input 102	Interpreted data of EnOcean data byte 2 with analog information.
Sensor01_DataByte_3	Analog input 103	Interpreted data of EnOcean data byte 3 with analog information.
Sensor01_Org_Byte	Analog input 110	Mapping of EnOcean ORG byte.
Sensor01_Receive_Time	Analog input 111	Time since last received wireless telegram, COV time for "Sensor Overdue".
Sensor01_Bi1	Binary input 100	Interpreted data of EnOcean data byte 0 with digital information.
Sensor01_Bi2	Binary input 101	Interpreted data of EnOcean data byte 0 with digital information.
Sensor01_Bi3	Binary input 102	Interpreted data of EnOcean data byte 0 with digital information.
Sensor01_Bi4	Binary input 103	Interpreted data of EnOcean data byte 0 with digital information.

Sensor01_ClearSlot	Binary value 100	The present value must be set to 1 to clear the sensor teached into the slot.
Sensor01_Mi0	Multistate input 100	Interpreted data of EnOcean data byte 0 with multiple states/information.

6.5.3 Description of further BACnet properties

6.5.3.1 Device object -> MAX master property

This property can be written between 0 and 127, and defines up to what address further users are polled on the bus. It is an MS/TP-specific property.

6.5.3.2 Device object -> object identifier

Each device in a BACnet network requires a unique device ID. The device offers two ways of altering the ID. The device ID is composed of the MAC address, produced by the address DIP switch, and a device ID offset, written by a BACnet object. The default as supplied for this object is 100. Device identifiers from 0 through 4194299 can be set by altering the device address or offset, after which the device is newly started and initialized.

6.5.3.3 Device object -> device name, description

These two properties are writeable, with a maximum text length of 128 characters. The object name property must also be unique within a BACnet network.

6.5.3.4 Sensorxx_Org_Byte object

This shows, in addition to the ORG byte of the teached-in sensor (in the present value), its EnOcean ID and the EnOcean profile and type of the transmitter. The ID, profile and type are contained in the appropriate property description.

6.6 Functional description

6.6.1 Teach in wireless sensor

To teach in a wireless sensor, the number of the required slot must be entered in the present value property of the EnOcean teach-in object. The next transmitter to send a teach-in telegram is teached in. After teach-in the present value is reset to 0. Teach-in is only possible to an unassigned slot.

6.6.2 Clear slot

Each slot is allocated a ClearSlot object. If the present value is set to 1, the previously stored information is rejected, and a new wireless sensor can be teached into the slot.

6.6.3 Receive time

Each slot is allocated a Sensorxx_Receive_Time object that detects the time since the last received wireless telegram of the teached-in transmitter. The time shown in the present value is incremented by the second and reset to 0 when a telegram is received.

The value in the COV increment property writes the transmit cycle of a COV message for this object. A telegram is generated if the time has elapsed and the sensor is overdue. As supplied the COV increment is 65535, which prevents sending COV messages. Times from 30 to 65535 seconds can be set.

6.6.4 COV procedure

The functionality can be selected with the multistate value object. Writing the present value property (1-3) selects the COV mode. When COV is active, the data byte objects of a slot that are used (four) are transmitted after a wireless telegram is received. When the time in the Receive_Time object has elapsed, this object is also transmitted as a COV.

7. Best Practice of BACnet plus EnOcean

7.1 Energy saved through energy efficiency

About 40% of the energy needs of industrial nations are consumed in buildings - where the potential for savings is quite enormous. How often have you driven past an office block late in the evening where all the lights are on, but only a handful of people can be seen still working? How often have you entered an empty room where the heating or air-conditioning has been going full-blast for hours? The necessity to save energy is not only driven by its cost. It is especially due to the prediction that many nations will simply not have enough energy in the future to satisfy their needs.

Energy savings, therefore, increasingly becomes a challenge. Costly schemes governed by demand for those regions highly affected are merely a short-term necessity. The most effective solution is to construct new buildings, or alter older ones, to make them energy-efficient. In a typical reconstruction case, it is possible to save more than 30% of the building’s energy consumption.

7.2 School renovated – 20% less installation cost and 30% energy saved

There are various reasons for renovating a building. Of course, a major reason is cutting the high cost of energy, which explains why an increasing number of builders as well as owners and property managing companies have started thinking about renovation. Older buildings in particular are often veritable energy guzzlers because they have little or inadequate insulation. Renovating a building with the objective of improving energy efficiency inevitably saves money in the long term. The important thing is to select the right system. At St. Joseph elementary school in Lacolle, Quebec (Canada), the decision makers opted for EnOcean technology for the room temperature sensing devices.

Saving Potential optimally tapped
Before its renovation, St. Joseph elementary school had no individual temperature regulation system but what could be called a dual-zone regulation for the entire school. As a result, it was often too cold in one half of the school and too warm in the other -- depending on the intensity of sunshine. This also meant that the school's energy consumption was very high. To cut the energy needed by heating and air-conditioning, and for extra comfort, the school decided in summer 2008 to install a system based on self-powered wireless technology from EnOcean. Sensors were put in place in 28 rooms, using light as their natural energy source and requiring neither batteries nor any external power supply. All room sensors are linked to a central BACnet system, controlling the temperature in individual rooms. The project was implemented by Regulvar, which served the school as consultant for the entire duration

Convincing Arguments
The main argument in clear favor of the EnOcean-enabled products was, in addition to speedy integration and simple planning, the attractive price compared to cabled solutions. The room sensors have enabled the school to enhance comfort and substantially reduce its energy needs. Plus, the new system implemented now allows metering and remote monitoring of energy consumption via internet, e.g. on behalf of the education authority. A further key argument was that the entire installation could be carried out without interrupting the normal running of the school. Something that is out of the question with a cabled solution due to the need to break open the walls for laying ducts needed to route the cabling.

Speedy and simple implementation
Installation of the whole system took just one week during October 2008 -- including installation of the central control system for the monitoring and government of energy consumption. As everything had to be in place and operational before winter sets in, the simplicity and speed of installation was a huge bonus for the school. As it turned out, the biggest challenge was finding the right positioning of the room sensors because the school has thick walls of

concrete and steel – normally a big challenge for wireless systems but no problem for the EnOcean devices.

A good invest

Choosing EnOcean's self-powered wireless technology saved the St. Joseph elementary school 20 percent in installation costs alone. The cost of implementing this wireless solution was 6000 Canadian dollars lower than for a comparable – but disruptive -– cabled installation. Together with the significant energy savings, the school expects a return on investment within two years. "To start with I admit that we were a little skeptical about this new technology", says Christine Halpin, Principal of St. Joseph elementary school. "But now we're very glad we chose it. We have more comfort, and we've cut our energy costs by a good 30 percent."

Fig. 5: Renovation undertaken at an elementary school in Canada enabled it to cut energy costs by some 30 percent

Fig. 6: Individual temperature regulation uses light as its natural energy source

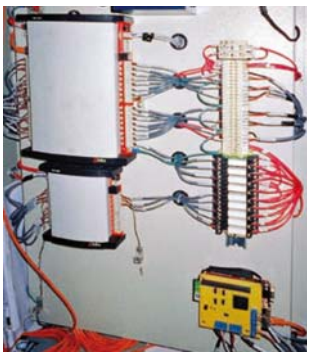

Fig. 7: The new system now allows metering and monitoring of energy consumption

Fig. 8: Visualization of room temperature sensors

8. Outlook

Future, second-generation interfaces will allow entirely bidirectional communication: Data generated by EnOcean sensors can be retrieved directly by BACnet actuators and controllers. BACnet controllers can in turn communicate with EnOcean actuators.

Typical applications are those revolving around energy savings, such as dimming or turning-off the lights when a room is empty; HVAC halting when windows are open; or standby mode of heating, ventilating, and air-conditioning when a room is not being used.

EnOcean technology has become a standard among architects and system integrators all over Europe, and is now well set to satisfy big markets in North America and the Near East. Unlike meshed wireless networks, the wireless switches are not active and do not transmit all the time—only when actuated. Interestingly, the electromagnetic emission of an EnOcean switch is much less than that of a comparable, conventional switch for a 100 W bulb. Initial medical concerns about the high-frequency radiation from wireless sensors were satisfied by scientific experiments. The use of EnOcean switches can thus be recommended, without concern, in hospitals, schools, kindergartens, and government and office buildings. Likewise, there are no environmental or biological concerns regarding attaching such a wireless switch directly to the headboard of a bed or to a bedside table.

About Regulvar Inc.

For over three decades, Regulvar has been setting the standard for excellence in automatic controls (HVAC) in Canada. Today, its open architecture platform also integrates critical systems like access controls, video surveillance and lighting control for a wide range of commercial and institutional applications. With over 400 employees, Régulvar is the largest building integrator in Canada. Its head office is located in Montreal, but it provides services to all of eastern Canada through twelve branch offices. Régulvar has successfully installed thousands of BACnet systems, using mainly Delta controls. The strength of its research and development team made it possible for Régulvar to develop many gateways enabling communication between BACnet and other protocols such as Lon, Modbus and EnOcean.

About Thermokon Sensortechnik GmbH

Thermokon has specialized in the production of sensors for the HVAC- and building control technology. Thermokon ensures an ideal exhaustion of saving potentials, e.g. by offering individually matching solutions. The receiver SRC-BACnet enables the connection of EnOcean sensors and wireless switches to BACnet.

About the EnOcean Alliance

Leading companies worldwide from the building sector collected to form the EnOcean Alliance and establish innovative automation solutions for sustainable building projects – and so to make buildings more energy-efficient, more flexible and lower in cost. The core technology of the Alliance is self-powered wireless technology from EnOcean for flexibly positioned and service-free sensor solutions. The EnOcean Alliance aims to standardise and internationalise EnOcean wireless technology, and is dedicated to creating interoperability between the products of OEM partners. More than 120 companies currently belong to the EnOcean Alliance. The headquarters of the non-profit organisation is located in San Ramon, California.

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