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Wireless gas detection with seamless integration into safety instrumented systems

GasSecure's GS01 unique low power detection principle has paved the way for wireless gas detection. Compliance with open wireless communication standards, together with GasSecure's patented SafeWireless™ communication concept, enables easy integration of the GS01 into safety instrumented systems in line with the IEC 61508 standard.

INTRODUCTION

GasSecure has developed a wireless infrared (IR) gas detector, the GS01, which operates with several orders of magnitude lower power consumption than today's standard wired gas detectors. The battery powered GS01 is a field device specifically designed for safety and monitoring applications. This paper explains field wireless communication in general and GasSecure's patented SafeWireless™ communication concept in particular. SafeWireless communication enables easy integration of the GS01 into safety instrumented systems (SIS) according to the IEC 61508 standard.

For most safety applications, continuous monitoring is required and a short response time (also referred to as latency) must be guaranteed when a safety critical situation occurs. Fortunately, for gas detection the average bandwidth requirement for wireless communication is modest. The primary challenge in designing a wireless safety system is combining a guaranteed short latency with very low power consumption. The GS01 consumes less than 5 mW power on average. This enables at least 2 years of continuous operation with two D-cell type batteries.

The GS01 gas detector is fully compliant with the SIL2 (Safety Integrity Level) guidelines as described in the IEC 61508 standard. This includes the communication with a safety controller, which implies that all network traffic must be fully controlled and loss of contact to any field wireless device must be identified immediately.

There are several communication standards and protocols to choose from for field wireless instrumentation. For safety applications, the ISA100 Wireless™ standard is the most promising contender for the following reasons:

- Object orientation facilitates the design of user-specific applications and the integration of safety protocols.
- Contract based communication (uplink and downlink) guarantees limits for bandwidth, latency, and priority.
- Device interoperability supports the ability of devices from multiple vendors to communicate and maintain the complete wireless network.

ISA100 Wireless is a wireless networking technology standard developed by the International Society of Automation (ISA). This ISA standard is intended to provide reliable and secure wireless operation for safety, control, and monitoring applications. This standard defines the protocol suite, system management, gateway, and security specifications for low data rate wireless connectivity with fixed, portable, and moving field devices supporting very limited power consumption requirements.

The GS01 gas detector from GasSecure fully supports the ISA100 Wireless standard and is therefore very easy to deploy in an ISA100 environment with compliant gateways and other ISA100 field devices.

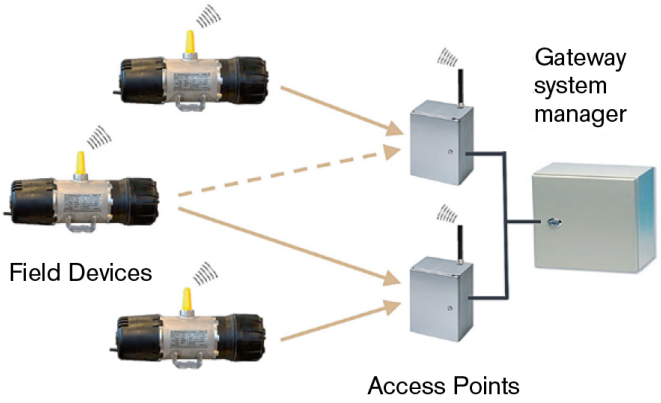

Figure 1: Example of a star topology network with paired access points. Secondary (back-up) communication links are indicated with dashed arrow.

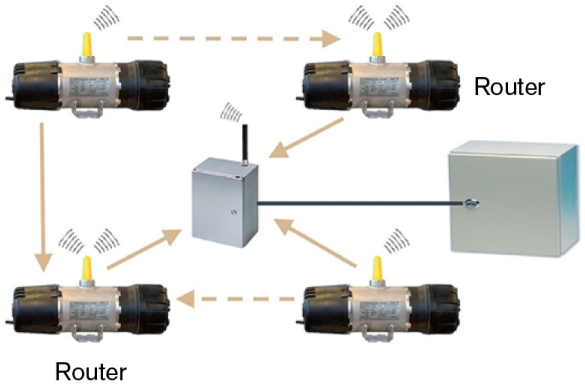

Figure 2: Example of a mesh topology network. Two field devices operate as routers. Secondary (back-up) communication links are indicated with dashed arrow.

WIRELESS NETWORK TOPOLOGY

The ISA100 Wireless standard distinguishes between field devices, for example sensors, valves, or actuators, and infrastructure devices i.e. devices that handle communication to other network devices and the backbone network. For both device groups a number of roles are defined. For field devices, the two most important roles are (A) Input / Output and (B) Router.

(A) A field device with the input / output (I/O) role provides data to and / or utilizes data from other devices. For example, the GS01 gas detector provides gas concentration data, whereas a positioner utilizes data.

(B) A field device with a router role (a repeater) can forward messages wirelessly. The router role is commonly combined with the I/O role, and many field devices including the GS01 are capable of routing messages on behalf of their neighbours.

For infrastructure devices, the most important roles are (C) System Manager, (D) Backbone Router / Access Point, and (E) Gateway.

(C) The system manager is a specialized function that governs the network, devices, and communications. The system manager establishes communication relationships (contracts) for devices in the network. The contract between the system manager and a device in the network allocates network resources to support the particular communication need of this device.

(D) A device with the backbone routing role acts as an open system interconnection between the wireless network and an internet protocol (IP) backbone. An ISA100 Wireless backbone router is commonly called an “access point”.

(E) A device with the gateway role describes the function that translates ISA100 Wireless messages to other formats such as Modbus®. A gateway marks the transition between communications compliant to the ISA100 Wireless standard and other communications and acts as a protocol translator.

Note that each of these devices may assume different roles within a network. For example, a workstation may assume the roles of gateway and system manager at the same time.
The simplest network topology is the star. In the star topology, an access point communicates directly with each wireless field device. This topology will minimize the latency, because each device is directly linked to an access point. With multiple access points, secondary (backup) links can be established (see figure 1).
The mesh topology (see Figure 2), in which additional wireless nodes are installed to act as relays, offers a more advanced set-up. The nodes may also have sensing capability (role A and B see above) and they may, or may not, be battery powered. Wireless mesh topology is used to extend coverage by means of intermediate links and may enhance communication reliability by providing redundant paths between devices. If the primary path of a field device is obstructed or becomes unavailable, the system manager can choose to transmit the data along the secondary path. This leads to very stable and predictable network availability.

The GS01 gas detector supports the previously mentioned topologies and it also allows for the combination of both, so that a network configuration can be designed that best satisfies the needs of the specific application. Another important parameter to consider in mesh-type networks is the number of allowed intermediate links (radio hops) from a field device to an access point. Increasing the number of hops allows networks spanning over a large geographical area. The disadvantage is increased latency of the data packets and increased processing load on the routers, which in turn will slightly raise their energy consumption. Note for the GS01, the published detector response time of 5 seconds is guaranteed for maximum two hops.

The deployment of a wireless gas detector network is simple. The gas detectors are placed in their preferred locations and powered on. Subsequently, each gas detector will communicate with the available routers and access points, obtaining an image of the network and the available communication paths and their quality. The aggregated information is stored in the system manager, which is responsible for setting up the communication relationships. The system manager updates continuously the image of the network ensuring that the communication relationships are optimum at all times and adapted to changes in the network topology.

SAFEWIRELESS™ COMMUNICATION

GasSecure's SafeWireless communication concept is designed to combine low power operation with a short response time (latency). In addition, this concept guarantees full control of all network traffic and immediately identifies any loss of contact with a field device.

Safe communication is based on cyclic exchange of messages i.e. all data packets need to be answered one-by-one. All communication is initiated by the safety controller, which will send a data packet that must be answered by the field instrument within the so-called process safety time. For hydrocarbon gas detection, this process safety time is commonly set to 60 seconds. Once the controller has received a response from the field device, it will immediately issue the next data packet. If the field device does not respond before the process safety time has elapsed, then this device is marked as unavailable in the control system.

For wireless data transfer it is advisable to allow several attempts for transmitting a data packet within the process safety time, in order to achieve robust and reliable communication. For the GS01, a reasonable balance between low energy consumption and robust wireless communication is to have 3 to 4 attempts within the process safety time, i.e. one downlink data transmission every 15 to 20 seconds.

In safety applications, a common limit for the acceptable interval from when hydrocarbon gas enters the detector measuring cell until the data packet with the gas concentration is received by the safety controller is 7 seconds. In order to fulfil this latency requirement, there need to be defined timeslots every two seconds for uplink data packets. The GS01 gas detector will therefore, during setup, request that sufficient bandwidth be set aside for this uplink transmission rate.

In the absence of hydrocarbon gas, these frequent timeslots will however not be used and the gas detector will limit communication to once every 15 to 20 seconds, thereby minimizing the average power consumption.

In the presence of hydrocarbon gas, the GS01 needs to report the detected gas concentration immediately and within the 7 second requirement. However, downlink data packets arrive only every 15 - 20 seconds and there is a one-to-one mapping between incoming packets and the device response thereto. In other words, once the detector has responded to a data packet it is unable to report gas concentration until the next data packet is received from the safety controller. This apparent dilemma is solved in SafeWireless by holding the response to a data packet until just before the following data packet is expected. This way the "blind" time is kept to two seconds and the detector is always primed and ready to report gas immediately. The concept with two modes of communication for "No Gas" and "Gas", as illustrated in Figure 3 and 4 is unique to the GS01 from GasSecure.

SafeWireless communication also fulfils the requirements of functional safety standard IEC 61508 for safety integrity level (SIL) 2. Most important, the following four error-handling mechanisms are supported: Sequence numbering, timeout in the absence of response, device code name, and data consistency checking. The purpose of these mechanisms is to detect failures of the safety device in terms of e.g. packet loss, unacceptable network delay, bit errors, and replay attacks.

Several options exist for implementing these required safety features. The approach chosen by GasSecure is to utilize a certified implementation of an open safety protocol. GasSecure has identified PROFIsafe over PROFINET, due to the widespread use of the latter in safety and process control applications.

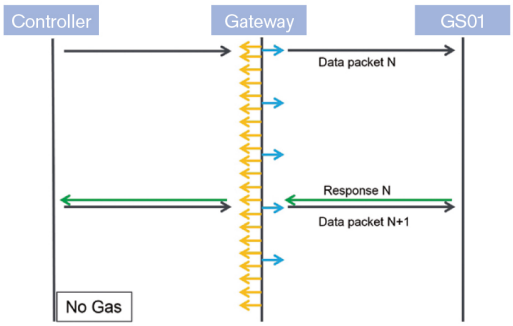

Figure 3: SafeWireless communication in the absence of hydrocarbon gas. The downlink data packets (black arrows) are typically sent 3 – 4 times per minute and answered by the GS01 (green arrows) just before the next packet will be sent from the controller. Yellow and blue arrows indicate allocated timeslots for uplink and downlink communication, respectively.

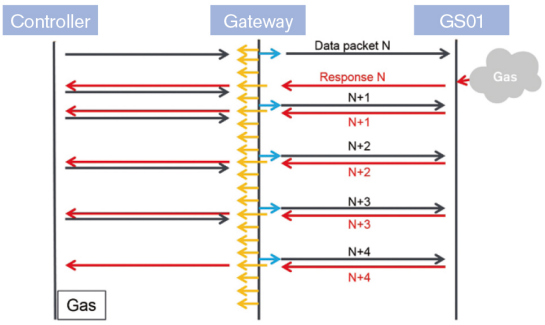

Figure 4: SafeWireless communication in the presence of hydrocarbon gas. On the occurrence of gas the instrument responds instantaneously (red arrow) using the first available timeslot (yellow arrow) for uplink communication. Communication is more frequent in the presence of gas i.e. all timeslots for downlink communication (blue arrows) are used now.

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FIELD TEST DATA

This section describes the integration of field wireless devices in complete safety systems (SIL and non-SIL) and addresses redundancy in such systems as well. The GS01 detector, like any other field device, must be paired with an ISA100 Wireless compliant gateway before it can communicate with the plant network. The gateway is the interface between the wireless network and the plant network and acts as translator between ISA100 Wireless and other protocols such as Modbus or PROFINET.

On the wired network Modbus and PROFINET are most commonly used as communication protocols for non-SIL and SIL applications, respectively. A typical system architecture for a non- SIL and SIL system is depicted in Figure 5. As shown in this figure, for SIL applications the PROFIsafe profile must be added as a separate communication layer. PROFIsafe is one of the few non-proprietary SIL-certified tools for safety communication loops and fully supports the aforementioned error-handling mechanisms. In a wireless gas detection system, PROFIsafe covers the entire communication path from the GS01 to the safety controller (end-to-end communication). PROFIsafe signals are only visible to the GS01 detector and the controller. Because of this so-called “Black-Channel” principle, the PROFIsafe layer (located above the standard protocol) has no impact on the standard bus protocols and is independent from the base transmission channels. Therefore, gateways do not require SIL certification not even when part of SIL certified communication loops.

For the gateway (including system manager), redundancy is typically implemented by two gateway units placed side-by-side and connected with a short synchronization cable. The primary unit is in operation mode, whereas the secondary unit is in stand-by, but at all times fully synchronized. Should the primary unit fail, then the stand-by gateway can take over operation within seconds.50 %LEL, notably one year after factory calibration and without any re-calibration in the field. Redundancy at the access point level is as per ISA100 Wireless standard referred to as Duocast. In essence, Duocast technology provides the function for a field

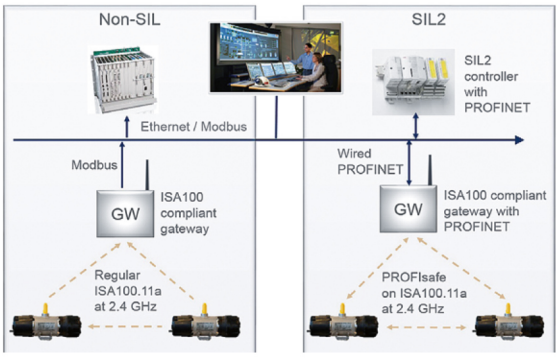

Figure 5: Wireless gas detection system architecture: Solutions for non-SIL and SIL2 systems.

wireless device to transmit the same data to two paired access points (see Figure 1). Thereby, the communication path is made redundant, and should the primary access point fail, then the secondary communication path is automatically available. Finally, having two or more controllers introduces redundancy at the highest level in the control architecture. This is supported by the ISA100 Wireless standard as well.

SUMMARY

The truly wireless GS01 gas detector is specifically designed for safety and monitoring applications. It fully supports the ISA100 Wireless™ standard for safe wireless operation of field instrumentation and is therefore very easy to deploy in an ISA100 environment with compliant gateways and other ISA100 field devices.

GasSecure’s patented SafeWireless™ communication concept enables easy integration of the GS01 into safety instrumented systems (SIS) according to the IEC 61508 standard. SafeWireless meets the requirements of fast response time, power efficiency and full control of network traffic. Moreover, redundant operation is possible for the entire safety system including the detector, gateway, and safety controller.

As a part of a complete system and to achieve a total solution for safety communication loops, the GasSecure GS01 utilizes PROFIsafe over PROFINET as communication tool for SIL applications. Overall, the GasSecure GS01 provides wireless gas detection with seamless integration into safety instrumented systems.

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