Analysis of wireless technologies for automation networking

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Abstract

Wireless technologies are challenging automation for new products and services. Like it happened in the past with Ethernet, the growing popularity of wireless among the general public is lowering the costs of wireless equipment. In the same way that Ethernet is being more and more spread in automation networking, wireless solutions are starting to find their place in automation networking, in spite of some scepticism about their robustness in a industrial environment. In this paper we show some of the advantages and issues of wireless network in manufacturing networking, namely the ability of exiting solutions to meet real time requirements, their security and safety issues, power issues and location awareness of the wireless devices.

Keywords: wireless, networking, automation

1. Introduction

Modern production systems have to cope with shorter product cycles, which often demand production to be reconfigured. Modern production systems have to exhibit large flexibility to cope with frequent changes that may involve the reconfiguration of the plant layout. To achieve a fast, reliable and flexible reconfiguration, since the 80's, in the industrial automation networks we have assisted to large evolution on the flexibility of device connections.

1.1 From Point-to-Point connections to fieldbus

From point-to-point connections there was an evolution to the creation of fieldbus. Fieldbus, in spite of some dispersion among standards, where achieving a steady state, but the introduction of wireless technologies will have a strong impact on industrial communications.

In the 80´s and 90´s, among a lot of standardisation activities [1], fieldbus were appearing as a standard way to interconnect sensors actuators and control equipment.

The main goal was to abandon legacy practices of point to point connections and replace them by a standard fieldbus, taking advantage on the decreasing hardware costs. The sensors and actuators would be equipped with CPUs and network controllers and connected directly to the network. Such solution would present a lot of advantages, namely [2]:

Data to be transmitted would have increased noise immunity, as digital communication copes better to noisy interference. Reconfiguration would become much easier because changing the location of a controller would need much less connections to be rewired. The devices CPUs would be used to perform local pre-treatment to the data.

This approach promised the distribution of the system intelligence all over the plant. The distribution level would eventually dismiss the controllers, leading to a system in which the tasks could migrate among the intelligent sensors, actuators and other devices connected to the network. Automation systems would become distributed, autonomous, fault tolerant and reconfigurable.

1.2. Now wireless !

The emergency of wireless had a strong impact of industrial communication architectures. It is really convenient to connect devices to the network, without the use of wires. Using wireless, tasks like re-cabling or installing a new device on an automation system can be made much more efficiently. But it is not just on saving costs or on the increased flexibility that wireless connections are important. Some applications need wireless connections intrinsically. For instance, when there are mobility requirements of a given device, wireless provide a good alternative to the use of sliding contacts or trailing cables. In wireless, not only the installation costs are much lower, but also the true self-reconfiguration of a system without any rewiring becomes possible as ever did before. Wireless technologies will play an important role in the future agile, wireless manufacturing plants [3].

1.2.1. Self reconfiguration

Self configurable wireless sensors networks, which are usual for other domains (military or environment surveillance) have applications in automation. In a self reconfigurable wireless sensor network, devices spontaneously assemble the network themselves without central administration, autonomously identify new devices and integrate them in the network, dynamically adapt to sensor nodes configuration, manage movement of sensor nodes, etc. When placed together, sensor nodes immediately know about the capabilities and functions of other smart nodes and work together as a community system to perform co-ordinated tasks and networking functionality. Wireless networking actually increases the scalability of an enterprise providing ease of expansion with minimal implementation and maintenance costs [4].

1.2.2. Fault Tolerance

In case of accidents or faults that might destroy the wired network, wireless devices might still be able to communicate. This increases the possibility of keeping the system work safely even in the presence of wired communication faults [5].

1.2.3. Real-Time Issues

In spite of the economical and structural advantages, some scepticism exists towards the use of wireless in industrial plants, especially in real-time systems. Wireless communications are subject to much more path loss. The signal strength decreases with distance exponentially. Wireless communications do not support full duplex communications, because when a device transmits, it is not able to receive on the same channels. The physical layer overheads are higher than wired solutions because of extra training sequences necessary to establish communication. The probability of getting channel errors is higher as wireless communications waves can be reflected or refracted and arrive to the receptor in multiple copies that will interfere with each other [6].

1.2.4. Safety Issues

The are also issues in safety, because wireless networks can be jammed unintentionally as by other equipment or by intentional criminal acts.

2. WIRELESS FOR AUTOMATION

2.1. Wireless issues

Many of the wired LAN protocols for medium access control rely on collision detection schemes, as it is the case of Ethernet. However, one of the most important differences between wired and wireless LANs is that there are no known solutions to efficiently detect collisions in wireless communications.

When using wireless for fieldbus, another problem arises: fieldbus messages are generally short. As wireless communications need to have more redundancy and preambles for training sequences, they are more suited to send long and not timed constrained messages, than short and time constrained messages. So the efficiency of the bandwidth decreases when dealing with typical fieldbus traffic.

2.2. Wireless LAN, PAN and WAN

There are nowadays available and under development many wireless technological solutions for Local Area networks (LAN), Personal Area Networks (PAN) and Wide Area Networks (WAN). PAN range is typically bellow some meters, LAN is in the order of tens to hundreds of meters and WAN range has an order of kilometres. Bellow we present some of the most active technologies and the importance they might have for satisfying today's requirements for automation.

2.2.1. WiMAX

WiMAX is a Wireless WAN being discussed in the IEEE 801.16 group. It uses focalised microwaves that can make point to multipoint transmissions. WiMax has a long transmission range (up to 50 km), but can also be used for last mile broadband communications. Combining multiple IEEE 802.16 channels for a single transmission could provide bandwidths of up to 350 Mbps. Originally, the 10 to 66 GHz band is used but the under the IEEE 801.16a standard it will also operate on the licensed and unlicensed 2 to 11 GHz band. The interest on these lower bands is that the signals can penetrate walls and most non-metallic obstacles and thus not require a line of sight.
WiMAX seems much more interesting for telecommunications operators that may use WiMAX links to access distant places and then have a local Wi-Fi signal distribution.
As for automation purposes, it seems that WiMAX will not have a strong impact in the flow shop but can be interesting for accessing data in distant sites with difficult physical access. Anyway WiMAX can be an enabling technology for remote access applications like for instance, tele-operation or tele-supervision.

2.2.2. Wi-Fi

Wi-Fi standards are based on the IEEE 802.11 specifications. Most common implementations support up to 11 Mbps (802.11b) or 54 Mbps (802.11g) with a typical indoor range of 30 m indoor or 90 m outdoor range.
As they use the 2.4 Ghz unlicensed band, there can be a lot of interference among these devices as well as from satellites, microwave ovens and high-end wireless phones. The 5 GHz band of 802.11a deals with much less inference, however it incurs in more difficulty to go through walls [7]. It is expected that the standard 802.11n will soon be available which goal is to increase the rate and range. The standard 802.11e aims to implement the quality of service functionality and provide deterministic media access.
Concerning automation, Wi-Fi devices have power consumption that, in some cases, are not suitable for the requirements of sensor/actuator networks.
However it is a mature technology and is helpful for the vertical integration in automation fields.

2.2.3. Bluetooth

Bluetooth is a Wireless PAN. It is a set of protocols with the physical layer based on IEEE 802.15.1 standard. It operates in the 2.4 Ghz unlicensed band. Bluetooth requires much less power than Wi-Fi, but the area covered and data rates are also smaller. Bluetooth 2.0 supports data rates up to 2.1 Mbps with a range that depends on the power class of the product. In most common implementations the range can be up to 1 m or 10 m depending on the power class.
For automation purposes, Bluetooth seems very suitable to replace serial cables for configuration and be used together with an HMI device to monitor and check and equipment for maintenance or diagnosis.
Bluetooth use for sensor networks seems not suitable especially because of the power requirements. Actually, other technologies, like ZigBee are available to provide low cost and low power solutions (but much lower rates) that are more suitable for sensor networks.

2.2.4. ZigBee

Zigbee is another wireless PAN. It is a set of protocols with the physical layer based on IEEE 802.15.4 standard. It operates in several frequencies including the 2.4 GHz band used by most Wi-Fi and Bluetooth devices. It presents a comparable or slightly higher range (10-100 metres) but a lower data rate (20-250 Kbps). The main advantages of ZigBee are lower power consumption and network self-reconfiguration. ZigBee devices are able to 'sleep' most of the time. The power consumption is reduced, making it possible to have devices that operate with a single battery for years. The standard provides star or meshed networks. In the latter case, it allows the coverage area to be extended when new nodes are added.
ZigBee is an emerging technology and it is not as mature as Wi-Fi and Bluetooth, but as ZigBee fulfils the requirements of low power and low cost, it is a promising technology for sensor actuator networks.

2.2.5. IrDA

IrDA is a PAN where all the data is transmitted by modulated infrared light. These protocols had a very promising start and gathered some popularity. Nowadays, many laptops, palmtops or mobile phones offer IrDA communications in the base configuration. Data rates of 1 and 2 Mbps are available in a 1m range. However, this solution never gained a lot of support and seems condemned because it requires unobstructed line-of-sight and a specific angle range [7].

2.2.6. UWB

Ultra-Wideband is a very promising solution for PANs. It is a technology where the communication is send by short-pulse electromagnetic waves, instead of the usual modulation of sinewave carriers [8]. It is claimed that UWB might achieve rates up to 500 Mbps in a 2 m range (or 110 Mbps in a 10 m range) operating in the same bands as other communication systems without significant interference. The occupied band is very large (500 Mhz or 20% of the centre frequency) but the hardware will consume just a few mW of power. Currently, there are two competing UWB standards: Cordless-USB from Freescale and Wireless USB from the WiMedia Alliance. The standard for Wireless USB, IEEE 802.15.3a, was under discussion but the discussion group voted to disband and it will be the market to decide which will be the winner.
For automation there seems to be a large domain of application of this technology. UWB might be a solution for demanding tasks like wireless closed control loops, as they can cope with the high requirements of small signal jitter and latency.

2.2.7. RFID

Radio Frequency Identification (RFID) is an electronic PAN technology for a wireless transmission of device identification. Their main goal is to replace the bar code labels. Passive RFID tags are powered by the microwave signal they receive through the antenna. They answer with a sequence of bits that defines its identification [9]. Compared to code bar labels they have the advantages of not requiring line of sight, not be limited to static data and have a longer read range. This turns them to the ideal device for product traceability. On the other hand they have the inconvenient of being more expensive (yet, a passive RFID tag will not cost more than some tens of cents). They use several frequency bands from 125 KHz to 2.45 GHz, but there are several standards driving their evolution.
Their use on automation is very promising for product tracking and warehouse management. Embedded within the equipment (or on the parts of it) they can stay there forever and answer with their identification whenever asked to.

2.2.8.NFC

Near Field Communication (NFC) is another PAN technology where a emitter provides a magnetic field and the receiver answers by modulating this field. The speeds are limited (106, 212 or 424 Kbps). The maximum operating distance is 1.5 - 2 m, but, in practice, small distances 0-20 cm are usually considered.
It is still difficult to say what impact this still immature technology will have on automation, but we may consider it somewhere around the impact of RFID and Bluetooth.

2.2.9. GSM 2G and 3G

The usual telecommunication GSM services provide larger coverage and higher rates with GPRS or UMTS. These technologies require an infrastructure of a service provider. They depend on a quality of service that cannot be always guaranteed for automation purposes. It seems that, like WiMax, these solutions are more interesting to telecommunications providers than for the automation.
However, in remote installations, like water supply systems, remote RF antennas, windmills, solar power plants, where the cost of local maintenance operations is high, cost savings can be done using the GSM based networks. In these applications, the generated traffic is usually small (order of a few bytes a second or even a minute) and there is no big issue if connection is momentarily lost. In this case, the use of these networks might reduce the number of costly maintenance visits.

2.2.10. Others

The are some other technologies that are not in the scope of this paper for several reasons, but they deserve some reference. *WiBro (Wireless Broadband)* aims to provide a high data rate wireless internet access with PSS (Personal Subscriber Station) under the stationary or mobile environment. It is primarily based in South Korea, but it is too soon to state about the success of this technology. *DECT* is a well-known technology for wireless phones and some works have been carried out for their use on automation.

3. Power Issues

The freedom to place wireless sensors anywhere in the factory plant or a building gets limited if those devices have to be connected to a main power source. Although power is generally available in the plants, it is often not provided at the precise location for the sensor placement [10]. There are several solutions for self-powering:

3.1. Batteries.

Battery operated devices seems a natural solution, if the low power consumption of the device allows a 3-5 year battery lifetime. This solution is used in temperature sensors located along one building to reduce the costs of heating, ventilation and air-conditioning systems [10]

3.2. Microwave

This is the solution used by passive RFID. The power needed to operate the sensor is taken from the power of the electromagnetic communication waves [9].

3.3. Energy harvesters

In this category we consider devices that obviate the need for a battery by exploring the energy present on the environment. This can be done, for instance, by using coils and magnets to retrieve energy from mechanical movements as in motors, pumps or fans, by using piezoelectric materials that generate power when mechanically strained or by using termocouples when a temperature differential is available [10], [11].

4. Location awareness

Wireless communications present another, somewhat unexpected, advantage: recent developments prove that it is possible to know the position of a device by measuring and correlating the signal parameters when they arrive to the wireless access points.

Wireless location finding emerged for safety reasons for cellular phones. According to the existing FCC laws that are being increasingly adopted by other countries, mobile phone providers have to deliver the precise location of the emergency calls, within 100 m of its actual position for at least 67% of the calls. The solution of installing a GPS receiver in each device has a lot of drawbacks (cost, outdoor only, need to modify the devices). The solution found is based in measuring the time delays and angles of the signal emitted by the device and fusion all the data to have an estimation of the device location. This approach has the strong advantage of requiring no modifications in the existing cellular phones. In Wi-Fi networks, a similar approach is used to provide more precise location of Wi-Fi devices [12]. Several new applications may arise like mobile advertising, assert tracking, fleet management, security and location sensitive billing [12].

For automation purposes the location awareness can have a positive impact. The location awareness of devices is important for Automatic Guided Vehicles (AGV). Usually AGV guidance and control systems compute the AGV position by making the fusion of data from the wheels incremental encoders (which are prone to accumulate errors) with the data of an absolute position. The absolute position can be given from triangulation or the passage by referenced places identified by sensors [13]. Recent developments turn the use of wireless into an easier solution for the AGV to recognise its absolute position.

For maintenance operations it is very convenient for the operator to carry with him a wireless palmtop or similar equipment that would guide him directly to the equipment that needs assistance.

Using wireless technology to track products and materials in their different phases would provide more efficient management. A quasi-total integration could be achieved if a similar development is made to identify the location of RFID tags [9]. Low cost active RFID cards, probably powered by energy harvesters with a location awareness system would be important for the management of a manufacturing site.

Even people location inside an area can be achieved with precision and commercial systems are already available, like the Ekahau Wi-Fi tag [14].

5. Security and safety

All wireless technologies face a security problem. As electromagnetic waves are easy to intercept and easy to jam. Using today's data encryption methods and spread spectrum techniques, it would be hard for a spy system to decode the protected information. Unintentional jamming can be solved changing to bands that might be free. Intentional jamming caused by criminal acts would be much harder to handle. Wireless can keep the communications working when a criminal act destroys the wired communications but is unable to perform if intentional noise is sent in all the operating bands.

6. Conclusions

In this paper we surveyed wireless solutions that are emerging and we analysed their impact in industrial automation networks.

We concluded that Wi-Fi devices have power consumption that might limit their use in industrial environments at the sensor actuator level but are suitable for vertical integration. On the other hand, Bluetooth devices have smaller power consumption and a smaller range. With a small range, Bluetooth might accommodate more devices in the same area, thus making a better use of the available bandwidth. The same arguments apply to ZigBee, which has the advantage of even lower power consumption and might be aplicable to the emerging UWB solutions.

Many of these solutions use the same public band, typically the unlicensed 2.5 GHz band. The CSMA protocols avoid many potentially destructive interference, however degradation is inevitable and several studies were already carried out to compute the throughput degradation when several of these solutions coexist [6].

Solution for self-powering the wireless devices is also under study. The classical solution is the use of batteries that might feed low power devices for 3-5 years. Other interesting solutions are arising with energy harvesters that are able to explore the energy present in the environment (e.g. mechanical or thermal). RFIDs can be consider in this class as they get the power they need to operate from the energy of the microwaves that carry the signals.

The location awareness of a wireless device is a new feature of these devices. This feature may have strong impact on services where the physical location of the device is important, like tracking, logistics, security or maintenance.

In conclusion we may say that there is still some scepticism about wireless networking in industrial automation. However, in spite of some drawbacks, there are many advantages on wireless networking that will provide new and innovative services and solutions for automation networking.

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