Software Technology

Machine-to-Machine Communication

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Although wireless communication is integral to our daily lives, there are numerous crucial questions related to coverage, energy consumption, reliability, and security when it comes to industrial deployment. Michael Weyrich, Jan-Philipp Schmidt, and I provide an overview of wireless machine-to-machine (M2M) technologies. I look forward to hearing from both readers and prospective column authors about this column and the technologies you want to know more about. —Christof Ebert

Imagine a widespread manufacturing plant equipped with smart machinery and RFID-enabled technology. In this plant, all the machines are interconnected and communicate through their sensors and actuators as they work their way through the manufacturing process. Operators use wireless pads and connect to production systems for diagnostics and manufacturing oversight. Machine load, status, and diagnosis data are further aggregated in enterprise systems for resource planning and production optimization. The machines receive usage feedback to adjust production schemes and therefore optimize cost and quality. The machines also communicate with their own manufacturers to request repairs or order new parts to avoid costly outages. Agent-based systems allocate load to machines in a distributed, often global, production setup to optimize supply-chain cost.

Future fantasy? No, this is a growing reality in what we call Industry 4.0. The factory of the future is far more agile than the approaches in today's flexible manufacturing. The smart factory connects the machines, devices, logistics, and humans to perform the necessary coordination ubiquitously and ad hoc. This concept, with manufacturing management organized to be super agile and hyper flexible, could even be viewed as the next Industrial Revolution (www.forschungsunion.de/pdf/industrie_4_0_final_report.pdf).

Machine to Machine

Industry 4.0's underlying need is effective and efficient communication between a plethora of production units, services, diagnoses, handheld devices, and enterprise systems in the push to design, manufacture, and service the good in question. This is fairly obvious to most forward-looking engineers, but the exploding number of often ad hoc connected sensors, controllers, and actuators is creating swarms of devices that are difficult to interconnect and organize in an industrial network.

For Industry 4.0 to prevail, communication technologies will need to efficiently connect machinery over varying distances in a flexible manner with high security, robustness, and availability at a low cost. One option is self-organizing logistics, but logistics becomes difficult once the number of product variants increases and production volumes fluctuate. The risk of supplier shortages or errors in the supply chain intensifies with complexity. Machine-to-machine (M2M) communication provides a solution by registering and tracking material, pallets, trucks, and so on.

Wired technologies have matured over the years and are widely used in M2M communication. However, they're rather static in their setup, depending on a wiring scheme that's costly to change, and demanding infrastructures and topologies that are well designed without knowing future demands. Cables play a key role in today's communication, but their continued use is questionable for future needs.

Wireless M2M communication is slowly entering the production process. RFID and WLAN technologies are cost-effective and seamless to install and operate on a global basis, but clearly don't yet address hard industry production needs. Engineers from domains such automation, automotive, transport, and medical all face the same questions when engineering a new automation project: Which wireless technologies are available to fulfill what type of demands from which applications? What are the criteria for choosing among the different wireless technologies on the market today? Which technologies are easy and cost-effective to engineer, build, and operate?

As a case in point smart factories can follow new way of organization due to advanced communication technology. Consider Figure 1 in which each device relevant to manufacturing is equipped with individual communication facilities. In the future, each product and its components and parts will carry communication tags, and those elements of production and logistics will remain traceable and manageable even in the event of unforeseen circumstances, such as global rerouting. Shortages and supply mistakes will be quickly rectified and machine diagnostics easily performed and resolved. Without wireless M2M communication, such an evolution isn't feasible.

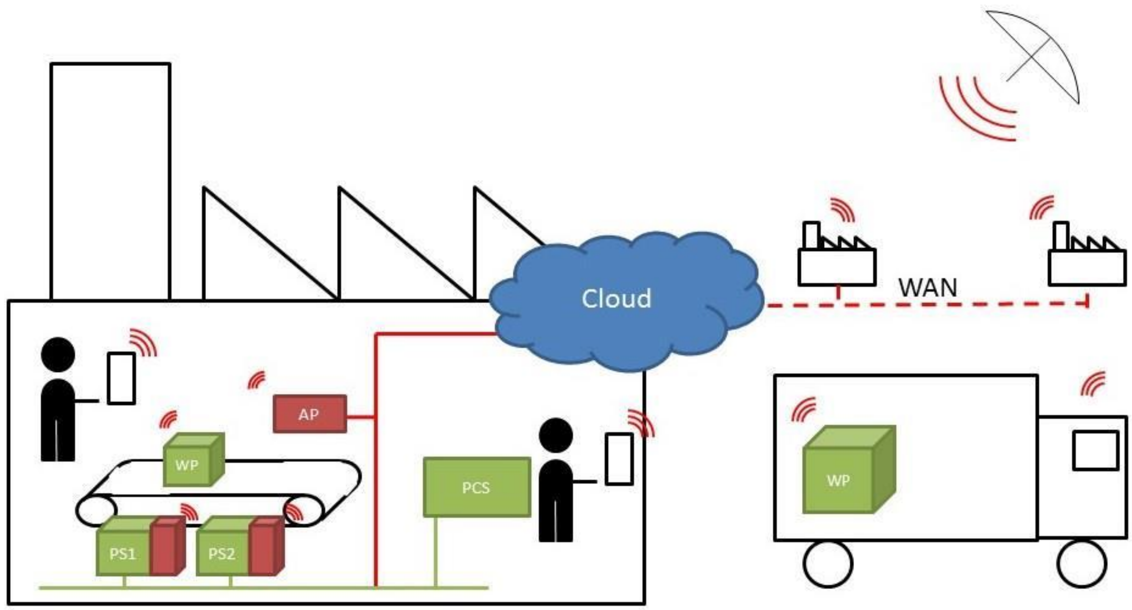

Figure 1. Communication in a smart factory. The figure shows selected elements of an automated facility. The work pieces and processing stations are equipped with advanced wireless communication to allow the tracking of material at any time. This way the materials trigger intelligently the manufacturing machinery and logistics which is a new way on how to manage a factory. (PS: processing station; WP: work piece; PCS: process control system; AP: access point; and WAN: wide area network.)

Wired or Wireless?

Networks can be both wired and wireless, but wireless M2M protocols are increasingly used today because they're convenient to install, use, maintain, and enhance. Wired technology is more traditional and widely applied due to its robustness and availability, which are especially in critical environments where security or explosive hazards must be considered. When such constraints don't apply, wireless technology can reduce engineering cost, provide access to remote or difficult locations, and has the advantages of not involving cabling. The biggest advantage is ubiquity: with wireless M2M, the position and status of anything processed in the factory is known at every stage and can be seamlessly connected to ERP and other enterprise-level IT environments.

To ascertain a wireless technology's suitability, you need to know the characteristics of the different offerings. Today, the physical transport layer is based on ISM bands: 2.4 GHz, 5 GHz, and 868 MHz. various standards are available, such as IEEE 802.11 for wireless LAN, IEEE 802.15.1 for WPAN/Bluetooth, or IEEE 802.15.4 for low-rate wireless Private Area Network (PAN). Unfortunately, there's still the very real problem of similar-frequency bands overlapping with each other, partially blocking frequencies or causing disturbances.

Obviously, M2M communication needs more than a discussion about standards for the physical and data link layers. New protocol stacks support wireless network technologies and protocols for communication with low bandwidth or limited memory consumption (http://postscapes.com/internet-of-things-protocols). The Internet of Things also has strong requirements for the address space in devices and the way messages are communicated.

IPv6 has facilitated M2M communication by resolving the address space problem, but with only a small percent of data used for the M2M application and the rest dedicated to message overheads, IPv6 isn't efficient for energy-constrained applications.

To counteract this, several energy-efficient wireless M2M protocols are available. Message Queue Telemetry Transport (MQTT) (www.mqtt.org) is a simple and lightweight messaging protocol designed for constrained devices and low-bandwidth, high-latency networks with low reliability needs. Invented in 1999, is currently undergoing standardization at Organization for the Advancement of Structured Information Standards (OASIS). The Constrained Application Protocol (CoAP), another energy-efficient protocol used to communicate interactively over the Internet, translates HTTP for sensors and switches, thereby facilitating machine connectivity to the Internet of Things with low overheads. The Data Distribution Service (DDS) protocol is a specific M2M middleware that provides real-time, dependable, high-performance communication between machines.

The Path Forward

Moving beyond mere protocols, we can find several industry-ready wireless technologies that vary in coverage, data rate, and usage. Wireless product solutions are usually based on IEEE standards but are increasingly defining additional specifications and providing product qualification programs, certification, and promotion.

Table 1 gives an overview of today's most relevant wireless technologies. It highlights nine current technologies for wireless M2M, along with a typical use case (including commercial availability of devices), encoding features for providing secure communication (range, throughput and infrastructure), efficiency, chip size, integration effort to add devices into networks, cost, and scaling potential.

Table 1. Overview on Wireless Technologies

	Use cases	***Sector***	***Range***	***Through put***	***Infrastructure needs***	***Effici-ency***	***Chip size***
LTE	Wireless communication for mobiles and data terminals	Tele communicatio n	10 km	150 Mbit/s	Complex infrastructure from provider	High	Small
WLAN	Wider Internet access	Multiple sectors	100 m	600 Mbit/s	Router, access points	High	Mediu m
Bluetooth	Product interface	Consumer	100 m	706.25 kbits/s	No special infrastructure, point to point (p2p)	Low	Small
Zigbee	Device control	Industry	100 m	250 kbit/s	Access points	Low	Large
Wireless HART	Sensors and actuators	Process, industry	250 m	2 measure ment	HART-Gateway to the fieldbus	High	Large
Industrial WLAN	Sensors and actuators	Process, industry	100 m	450 Mbits/s	Access points, gateways to fieldbus	High	Large
EnOcean	Energy harvesting, smart homes	Building, automation	30 m	125 kB/s	Transceiver modules	Very low	Large
RFID	Non-contact identification and tracing	Many industries	6 m	100 kbit/s	Tags, scanner	Very low	Very small

NFC	Radio communication	Smartphones	10 cm	424 kbits/s	Smartphones, tags	Very low	Very small

Key decision drivers for the choice of products include investments for hardware, costs, and speed to adjust and extend a network and integrate new devices. However, additional requirements also affect the final choice: energy efficiency, chip size, and security.

For instance, if a wide area wireless connection is required to interconnect vehicles for diagnosis, vehicle ad hoc network, and fleet management, LTE is the technology of choice. It offers reasonable coverage in many regions.

However, WLAN and Zigbee would be the choice for service technicians in industry using mobile access devices. Both networks provide a high data rate, don't need centralized communication infrastructures and overhead, are secure, and can be provided with reasonable coverage in manufacturing sites. NanoLOC, a technology for tracking objects based on the Zigbee Standard, is suitable to detect work pieces in widespread industrial production sites.

Some use cases require low-range object identification or near-field communication (NFC). RFID is an established technology for identifying objects such as work pieces; NFC can help exchange data between objects in close proximity.

Many special interest groups have emerged around wireless technology and the attempts to use it to evolve and promote product solutions. Bluetooth has an interest group of more than 20,000 companies, and the ZigBee Alliance hosts a thriving global ecosystem of businesses, universities, and government agencies to grow that particular standard and a solution space with products around it.

Table 1 cont. Overview on wireless Technologies Continuation

	Integration effort	***Cost***	***Scaling potential***	***Encoding***	***Market Readiness***	***URL***
LTE	High	Low	Low	AES128	matured	www.3gpp.org/technologies/keywords-acronyms/98-lte
WLAN	Very high	Low	High	e.g. WPA2	matured	www.radio-electronics.com/info/wireless/wi-fi/ieee-802-11n.php
Bluetooth	Low	Low	High	AES128	matured	www.bluetooth.com/Pages/what-is-bluetooth-technology.aspx
Zigbee	High	High	High	AES128	matured	www.zigbee.org/About/AboutTechnology/Standards.aspx
Wireless HART	Low	High	Low	AES128	niche markets	www.hartcomm.org/protocol/training/training_resources_wihart.html
Industrial WLAN	Very high	High	High	WPA2	niche markets	https://a248.e.akamai.net/cache.automation.siemens.com/dnl/TM/TM0MTMzAAAA_90880063_HB/22681042_Aufbau_IWLAN_DOKU_V30_en.pdf
EnOcean	High	Low	Medium	ARC4 or AES	certain sectors	***www.enocean.com/fileadmin/redaktion/pdf/articles/perpetuum_radio_standards_en.pdf***
RFID	Very low	Low	Low	not required	matured	www.rfid-journal.de/rfid-technik.html
NFC	Low	Low	Low	not required	upcoming	www.nfc24.info

The HART Communication Foundation and products such as Industrial-WLAN are more focused on the industrial automation application fields. Once a wired HART or Profinet infrastructure is available, Wireless-HART or Industrial-WLAN make sense in terms of compatibility: existing industrial wired infrastructures can be connected easily, especially remote sensors or diagnostics that are difficult to access. The EnOcean Alliance provides applications with low power and energy harvesting needs, and EnOcean-enabled switches can be powered by batteries or harvested energy because the transmitters have very low power consumption.

However, when it comes to energy-efficiency, M2M protocols will have a considerable impact. For example, Bluetooth provides several energy-safe modes when no communication between master and slave is necessary. Moreover, RFID tags can be activated with transducers, before data can be written and read, thus boosting energy efficiency.

With the rapid progress toward Industry 4.0 applications and smart factories with multiple networked devices, highly specific communication protocols will continue evolve. Our entire engineering environment will change based on these new ways to interconnect devices, machines, and products, starting with production and covering the entire product life cycle. With big data and the Industry 4.0 vision, some sparks have been ignited, but the fire will grow much bigger than what we can imagine today with manually installed communication systems.