Connectivity for mobile systems

This article describes how mobile CAN-based systems and machine-on-wheels can be connected to the Internet

Figure 1: Smartphones are increasingly used to provide Internet connectivity for mobile CAN-based systems (Photo: Moba)

If you have not heard buzz words like Internet of Things (IoT), Machine-to-Machine communication (M2M), or Industry 4.0 you might have spent the last few years on Mars or in an information black out. With the emergence of the Internet and low-cost data transmission possibilities, we started to connect a wide range of things (like sensors, machines, etc.).

But not only on the technical side, we as humans also adapt rapidly to this era. In fact, there is already a term for digital natives: Generation C. Members of this generation connect to people and things in ways not imagined in the past. Social media, gadgets, and wireless technology allow Generation C to share data on the fly.

This process is often split up into two distinctive parts. First, there is the collection of data. This can be either traditional sensor data like temperature or pictures and videos for social networks. After the collection, most often we are trying to get useful information out of the collected data. With the new wave of smart and self-learning algorithms – here we have a new range of other new buzz words like artificial intelligence or neuronal networks – it feels like we are still in the early stages of turning huge amounts of data into actionable information (this can range from new decentralized weather monitoring and prediction systems to face recognition algorithms). Here, the focus will be on the connectivity aspect of the process or in other words how all these devices can be connected to the Internet and data can be exchanged. Even more specifically on mobile systems with CAN or CANopen networks and how they can connect into the Internet and make IoT and Industry 4.0 reality.

Therefore, we are firstly looking into the current situation, circumstances, and some constraints in which mobile CAN-based systems are operating. Followed by a look into technologies how data from CAN networks can be transported into the Internet. Finally, some connectivity applications scenarios are outlined and how they could be implemented.

Situation

CAN as a central communication technology in mobile systems is widely found. Naming just some representative examples is almost impossible. Our customers operate on- and off-road trucks in various shapes and heavy construction machinery in general. All of these machines and systems rely on one or multiple CAN networks.

Traditionally, these machines and systems have been black sites regarding connectivity. There are CAN networks on the machine itself but there was no need to communicate with the outside world. In the 1990s, mobile phones allowed drivers, operators, and support technicians to connect to the outside world (at least audio) but the systems itself not. According to different predictions, there are today up to 70 % of these machines and systems out silently doing their jobs.

Technology

So, if there are so many machines and systems out there, which might need to become part of IoT, what are the technology options to make this happen?

First of all, there is an architectural or systemic question. Like cars or mobile phones, the first idea could be that every machine has its own access to the Internet. That is definitely true for most of the machines with CAN networks. Trucks in all shapes often operate alone or at least drive routes by themselves. Therefore, a separate connection per machine is necessary. However, there are other cases in which a group or a fleet of machines work together in well-defined areas, like jobsites or mines. In these scenarios, it could be possible that only one machine or system has access to the Internet and all other machines re-use this connection.

Case 1 - Machines with own Internet connection

Let's start with the first case in which each machine has its own Internet connection. The most obvious solution is the use of a mobile network. With the current LTE speed it is possible to reach up to 300 Mbit/s download and 75 Mbit/s upload speed. This should be easily enough to transport data from multiple CAN networks. Even with the older mobile network standard 3G (at least 2 Mbit/s) it should be easily possible to connect machines into the Internet. However, this touches on the topic of coverage. In large cities LTE and 3G (as backup) are widely available. But less populated and rural areas in general have limited or no mobile network coverage at all. For example, there is currently a major motorway (Autobahn) ▷

construction project underway in Germany connecting the cities of Kassel and Eisenach. The motorway leads to larger areas without any mobile coverage, making it difficult to connect to the construction machines on this jobsite. Another point is the set-up and ease of use. Modern solutions cover the complexity in setting up SIM card, providing therefore a good and easy experience for users of such solutions.

To be able to use mobile networks, it is usually necessary to sign a contract with one of the mobile network operators. Here are two important things to mention. Firstly, mobile network operators often separate their networks on country boundaries. So, if machines are used across borders, it might be necessary to check the pricing. Within the European Union roaming costs become a thing of the past, however in other regions of the world, this still needs to be considered. Secondly and related to the first point, mobile network operators charge monthly fees for their services. This is fine for most of the applications, however if the connection to a machine and its CAN networks is only needed occasionally, a monthly fee for mobile network operators is perceived as high costs.

Here, smartphones started to become a major role to provide connectivity even in these cases. Gateways which provide access to CAN networks via WiFi or Bluetooth are connected to the smartphone, which acts as a tethering device or in other words as central access point into the Internet. The advantages and differences between WiFi and Bluetooth are discussed in more detail later on in case 4.

Case 2 – Internet connection via WiFi hotpots

The second option how individual machines and their CAN networks could connect to the Internet is to use openly available WiFi hotspots. Like mobile network coverage, this is most often available in larger cities and it might be difficult to get hold of a WiFi hotspot in rural areas. Notable exceptions are the countries of Estonia and Lithuania, which have – according to several reports – the best and widest-ranging WiFi hotspot networks in the world. Here you might be able to connect to a WiFi hotspot even in rural areas.

Case 3 – Internet connection via satellite-based communication

Finally, it might be possible to use satellite-based communication (e.g. Iridium or Inmarsat) in areas of missing mobile coverage. A prime example is Australia. In most parts of the sparsely populated Outback there is no mobile coverage available. Due to the large distances, there are solutions available in which trucks report important data through satellite-based communication. Unfortunately, the use of satellite communication is very expensive compared to the usage costs of mobile networks.

Case 4 – Internet connection through a central access point

As mentioned earlier, the second architectural option is the use of a central access point to connect into the Internet, which is then re-used by other machines and systems. The central access point faces the same considerations in ▷

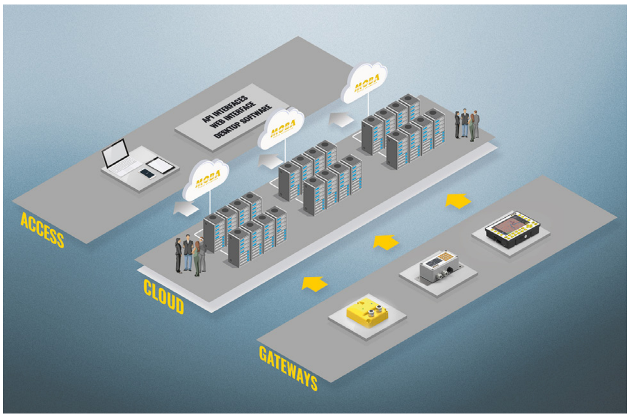

Figure 2: Typical setup to connect mobile CAN-based systems to the Internet (Photo: Moba)

regards how to connect to the Internet as described above. Most often a connection via a mobile network can be a viable solution. But there might be other aspects to consider as well. In such a scenario, there would be only one connection, therefore the costs are limited and it might be possible to use a high-quality and very reliable solution. Also from a risk point, it might be important to focus on reliability as the connection would be the single point of access to a fleet of machines. In other environments like mines, it might also be possible to set-up an additional IT infrastructure to provide connectivity. Here, often WiFi routers are installed, allowing machines access to the Internet.

Besides the central access point, it is crucial how other machines can connect to this access point. The two most common technologies are WiFi and Bluetooth. Both have distinctive features, which can both be suitable technologies for different machines and use cases. Here, five specific characteristics are highlighted.

The first aspect is range. Bluetooth has an intended range from 10 m up to 100 m. In the WiFi world, there are no pre-defined ranges. Here it depends on aspects like transmission power and antennas. To complicate matters, a lot of countries have specific regulations around maximal antenna power output. However, the current distance record is held by the Swedish Space Agency with 420 km (260 miles) – using special equipment. But even with standard equipment it is likely to reach 200 m (656 ft) outdoors. Another aspect is bandwidth. For Bluetooth the maximum bandwidth is 24 Mbit/s. Whereas WiFi allows up to 862 Mbit/s with its newest standard. This is even higher than the current LTE standard.

Related to range and bandwidth is power consumption. It is easily imaginable that WiFi creates a stronger signal (and therefore consuming more power) as WiFi signals need to travel further and with higher bandwidth. A study from the University of California at Los Angeles has shown that in worst case scenarios Bluetooth needs less than 3 % of the power WiFi would need for the same task. Another very interesting and sometimes overlooked aspect is the routing capability of the different technologies. With routing it is possible to send data between different networks. In fact, routing makes (access to) the Internet actually work. Since WiFi is based on the same protocols used in the Internet, it supports routing. Bluetooth usually does not support routing. The most common use case is a so-called point-to-point connection (like a smartphone and hands-free car kit). In other words, it is necessary to convert the data received from Bluetooth, so that it can be used and routed in the Internet.

The last aspect is set-up and ease of use. Even though the people who struggled with a Bluetooth pairing lately, might disagree, but – in general – Bluetooth is easier to set-up. WiFi now has possibilities like WPS, which reduce set-up hassles, however it can get somewhat more complicated with network names (SSID), passwords, network structure, and so on.

Application scenarios and their implementation

After looking through the available technical options to provide Internet connectivity for CAN-based systems, let's have a look at three different application scenarios and how they could be implemented, namely remote support, machine-related data, and production-related data. The three scenarios are described separately here, but often they are used together at a machine or system.

Remote support

Remote support for machines is often the first idea, which comes to mind if it comes to Internet connectivity. Remote Support stands for a wide range of options and possibilities. It could be that a new machine is tested in the field and the engineering department wants to check the machine regularly or if customers report problems with the machine. Another use case could be that the machine is in the early stages of production and the chance of a software or firmware update is high. Or maybe machines are sold worldwide and in some regions of the world the support or dealer network is not as extensive as in the domestic markets. Or maybe the users of the machines manage very time-critical processes and therefore any down-time is extremely critical and expensive. Fixing the problem as quick as possible is therefore crucial. Yet another use case is the possibility to train users remotely. Instead of trying to explain how to use the system on the phone or sending a technician to the user, the screen is shared and the support technicians can remotely train and provide best practice experiences.

Implementing remote support usually means that each machine has its own device or possibility to connect to the Internet. Using the other approach of a central access point might work in some circumstances, however if the access point needs support the whole fleet of machines and systems might also not be connected to the Internet. Due to the wide range of options which are summarized under remote support, the used technology will be different. If the timely access to the machine is highly important, a SIM card solution or in extreme cases even a satellite-based solution are the right choice. On the other end of the spectrum are solutions in which the support can wait until a machine is back in the workshop or yard. The solution here would be that the machine connects via WiFi (through an existing WiFi network) into the Internet. For price-sensitive markets or only occasional accesses to a machine, which do not want to pay a monthly fee to mobile network operators, the solution with a smartphone acting as tethering device is a very interesting solution. ▷

Machine-related data

Machine-related data, as the next application scenario, are somewhat related to remote support, in the sense that support is hopefully reduced due to the usage of machine-related data. These data are characterized as all data which directly belong to a machine. Obviously, this varies with each machine and system, but recurring examples are information about oil (pressure, remaining oil, status of oil filter), remaining fuel, engine status (idle, engine speed) and much more. With these data a wide range of things can be accomplished. To mention a few, the already mentioned support can be better planned. For instance, if an oil filter shows first signs of problems, an exchange can be scheduled and therefore an unexpected failure of the machine in operation can be avoided. Another use case of machine-related data is the monitoring and improvement of machine utilization. If a machine is used only occasionally or not at all, it might be better utilized at a different jobsite, plant, etc. (given that it is not a specialized machine which is needed specifically there). A last machine-related data use case example is the improvement of productivity. For example, if an engine is most of the time idle, it burns a lot of fuel (and creates pollution) and takes hours away from the machine's warranty. Therefore, turning off engines if they are not used can save money and air pollution.

Similar to remote support, the technical implementation depends on the users' requirements. If, for example, a rental company wants to check that a machine is only used within the terms agreed in a rental contract, a solution with a SIM card is most likely suitable. But if the focus is on oil filter status, it might be enough to connect the machines into the Internet as soon as they are back on the yard. If the machine is part of a fleet, the use of a central access point is also a viable solution.

Production-related data

In contrast to machine-related data, production-related data focuses on the processes or tasks the machine is currently working on. A practical example would be fill or cut information from an excavator. Very often excavators are used to fill an area (filling) or remove a pile, hill, dig a whole, and so on (cut). In this case it could be very interesting to know how far the task of filling or cutting is progressed. Another use case could be that the plan changes on what needs to be filled or cut and the updated plan needs to be sent to the operator. In general, the processes and tasks are specific to machines and the applications in which they are used. But there are some recurring patterns which can be identified across a wide range of processes and tasks. Firstly, the degree of task completion is, as already mentioned, very often of interest. Secondly, reports or documentation about the tasks or processes done are important. For example, in road construction the asphalt temperature can be measured throughout the paving process. If the temperature stays within a certain range, it is a proxy for a high-quality asphalt and therefore high-quality roads. Thirdly, any problems or exceptions form the process should be reported; often in form of warnings, errors, and exceptions. Lastly, process or task updates need to be sent immediately to the machine. This could be the already mentioned plan update for excavators but also a wide range of other information and parameters like the maximal boom length of a crane based on current weather conditions.

Implementing the connectivity of production-related data requires usually a constant Internet connection. In this scenario, the use of mobile networks is the dominantly used technology, whether each machine has a separate SIM card or there is a central access point for a fleet of machines (e.g. a WiFi hotspot in a mine). If the process or task is highly critical or creates a lot of value for the user, it might be helpful to use satellite-based communication. It is worthwhile mentioning that production-related data can become large in quantity. Therefore, it is important that there is not only a connection but a connection with enough bandwidth to transfer all the data.

Summary

The Internet of Things and Industry 4.0 are currently filled with life. In this article, we had a look on how mobile CAN-based systems and machines can be connected into the Internet and therefore become part of IoT and Industry 4.0. Depending on the users' needs there are well-established technologies available to connect machines and systems to the Internet. Most prominently is the use of mobile networks either for each machine or as a central access point for a fleet of machines. The use of a smartphone as a tethering device, WiFi, Bluetooth, satellite-based communication also are important technologies for connectivity and might become even more important in the future. All these technologies are used in application scenarios found in mobile machines and systems. These scenarios, namely remote support, machine-related data, and production-related data, represent a wide range of use cases and applications which make IoT and Industry 4.0 reality. ◀

Author

Matthias Limbach
Moba Mobile Automation
mschmitt@moba.de
www.moba-automation.com

CAN automates crop cultivation

The described relatively simple system illustrates how CAN networks could be used to control the environment within a commonplace horticultural application.

Research conducted by the University of Minnesota has estimated that, given that current projections expect the global population to be over 9 billion by 2050, agricultural output would need to increase by approximately 60 percent in order to avoid major food shortages being witnessed within this period. At the same time dwindling oil reserves will mean that biofuel production has to be ramped considerably to keep pace with heightening demand (market analysts at Navigant Research have recently predicted that annual biofuel shipments will rise by around 35 % to 40 % between now and 2020). These two dynamics when factored together will put a great deal of strain on the planet's crop production capabilities. In response, more comprehensive use of technology is going to be needed so as to increase crop yields.

CAN is the dominating in-vehicle network. CAN networks are also used in industrial automation (mainly in embedded front-end units) and building automation (climate control and lighting control systems). CAN presents engineers with an easy to implement, lightweight, error detectable network protocol that is capable of supporting communication at 1-Mbit/s data rates over distances up to 1 km without repeaters. It is, that the implementation of CAN is starting to see substantial uptake within agriculture and horticulture, where an increasing degree of automation is now being mandated. These industries of course generally need large expanses of land on which to grow their produce and often field repair/maintenance could prove to be expensive - so a reliable, far-reaching, very economical networking medium such as CAN displays all the main attributes to make it appealing.

If an agricultural/horticultural automation implementation is to be fully effective, data concerning soil condition, ambient temperature and humidity levels needs to be continuously acquired, in order to ensure that these key environmental parameters are maintained at optimal level to maximize crop production. In addition, light sensors can be used to monitor how well the crop is being illuminated in different areas. Once all this data has been transported back it can be analyzed and actions taken if needed. By way of an example let's take a large greenhouse. If the light levels in a particular area were consistently found to be lower than elsewhere in the building, the LED lighting at that location could be turned up to provide greater illumination and thereby encourage great photosynthesis to occur. Furthermore, if analysis suggests that alteration of the light wavelengths will be advantageous in terms of crop growth then the balance of RGB-LEDs can be altered accordingly.

With regard to a large outdoor agricultural facility, if data retrieved suggested (for instance) that the soil's moisture content was too low, the operative examining these figures could subsequently initiate the carrying out of additional water spraying to alleviate the issue.

The benefits of greater automation in agriculture and horticulture are clear. There is a problem, however, that needs to be overcome if its more extensive proliferation is to be secured in an acceptable timeframe. This is having the electronic hardware available that can firstly cope with all the fairly heavy data processing involved in a cost-effective manner and then; secondly, have the connectivity features that are required.

The shown example in Figure 1 illustrates how a CAN-based infrastructure may be used to control the environment within a commonplace horticultural application. Here parameters such as soil moisture, air temperature, air humidity and light levels are all being addressed via the array of appropriate sensing devices that have been incorporated. These are employed to collect vital environmental data from different locations and then feed it back so that it can be examined. They furnish the operative with greatly enhanced visibility on how different environmental conditions are effecting the crop and enable well informed decisions to be made about what changes might need to be made to improve yields.

The root node collects sensor data that has been captured at the child nodes (1 and 2). It then transmits the data (concerning characteristics of the soil, air, etc.) to an Android application via a Wi-Fi module. The Android application (which can run on a wirelessly connected portable electronics platform, such as a tablet or laptop) is able to monitor all the information coming in simultaneously from that numerous connected sensors within the system. From ▷

Figure 1: Schematic of a horticulture automation system (Photo: FTDI)