metrilog

M2M: The New Age Of Telemetry

White Paper

Metrilog Data Services GmbH, Am Concorde Park 2/F, A-2320 Schwechat, Austria
Tel: +43-1-890-1236-0, Fax: +43-1-890-1236-21
http://www.metrilog.com

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Executive Summary

The Internet revolutionized many aspects of people's day to day life. The penetration of broadband is reaching almost everywhere. The mobile communication is getting to the Internet too, as data services are multiplying and growing in importance. However, most of the Internet usage today is still human oriented.

As the number of people on the Internet is reaching towards saturation, the next technological big-bang is on its march: Machine to Machine communications (M2M). While there are over 800 million PCs in use today [1], the number of machines that could potentially benefit from being connected to the Internet surpasses 18 billions! [2]

More and more machines are using the Internet to communicate either with other machines, or with people. Imagine a vending machine: instead of paying it a visit to find out if there are enough cans/bottles, why not let the machine itself tell you this? Or what if you would like to turn on the heating system from the road when coming home? Or if the merchandise entering a shop is scanned by means of RFID tagging and automatically added in the shops' inventory databases? There are plenty of such examples.

M2M has been possible through the convergence of several technologies: the microprocessor, the networking and the wireless communications. M2M by itself will stimulate the further development of pervasive computing, which can be expressed by:

anytime — anywhere — any device — any data

Traditionally, telemetry (from Greek roots tele = remote, and metron = measure) has been used to fulfill the people's needs for remote data acquisition and control. However, due to the technology advances, implementing telemetry systems became more accessible as costs went down. M2M technology continues where telemetry left: wireless telemetry systems today cost substantially less compared to what they did 10 to 15 years ago. Applications that were previously not economically feasible are now cost effective.

M2M brings to telemetry discipline through open standards and protocols. The extraordinary expansion of mobile digital telephony, especially GSM (Global System for Mobile Communications) stimulated the development of telemetry applications. GPRS (General Packet Radio Service) which is piggy-backed on the free capacity available on the GSM networks offers the possibility to communicate cheaply from virtually everywhere. Open protocols (TCP/IP, HTTP) and formats (XML, WBXML) were embraced from the Internet community thus adding interoperability between different telemetry systems.

[1] IDC study (2005)

[2] Based on the number of micro-controllers sold to date

Metrilog Data Systems offers an end to end solution for M2M applications which is based on open technologies and protocols. This paper details the advantages of using Metrilog M2M technologies and services when compared with traditional solutions.

Traditional Telemetry Solutions

In order to better understand a basic telemetry system, a simplified overview of a traditional telemetry system is described in this section. Actually, there are a lot of different applications, each having its own peculiarities, but basically almost all of them can be assimilated to the outline described below. A typical telemetry network is based on the following components:

- Sensors/Actuators;
- Remote Terminal Units (RTU);
- Base stations—also known as receivers, gateways or central collection points;
- SCADA software, usually dedicated software.

The data flow of such a network is depicted in the picture below.

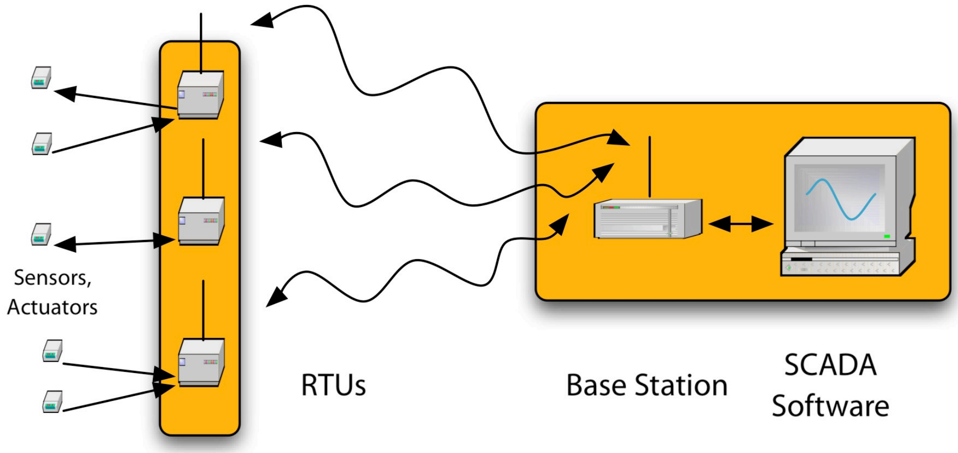

Fig. 1. A classic telemetry system

Essentially, a user needs either to know what happens in a remote place ("do I need to start the heating system?"), send a command to a device in a remote place ("let's start the heating system!"), or both. These are the generic cases where telemetry can help, however in practice the world of telemetry is a bit more complex.

The components required to put together a telemetry system are presented succinctly below.

Sensors/Actuators

Sensors are used to "feel" the environment by transforming different physical values into their electrical counterpart; actuators do the reverse, they convey an electrical impulse sent by the user to enable or disable a function (open a door, switch a valve, etc.). There are many types of sensors and actuators, and almost as many different standards. Basically, they are divided in two main types: analog and digital. The analog sensors can deliver information as a voltage, current, pulse counters, etc. Digital sensors typically include a micro-controller and additional electronics (e.g. analog to digital converters—ADCs) that perform the conversion of the analog values to a digital output, typically a serial bus. They are also called *intelligent sensors*. Unfortunately, there are still too many analog sensors in the telemetry world, but things are constantly improving.

RTUs

An RTU (Remote Terminal Unit) is a device that assures the transmission of the measured values provided by sensors to a base station, as well as the other way round, gets the information from the base station and feeds it to the actuators. There is a large variety of RTUs, most of them offering additional functionality like e.g. data logging (buffering data if the communication channel is temporarily not available), power management, PLC functions (Programmable Logic Controller) and so on. The communication systems used vary, from wired serial to wireless and satellite communication.

Most RTUs are based either on proprietary wireless, or GSM/cellular analog data transmission. Each method has its advantages and drawbacks.

The proprietary wireless RTUs are relatively expensive to built and difficult to install; the distances reached are typically in the range of several kilometers or tens of kilometers. On the other hand, the operating costs are quite low, in many countries this type of communication is free, or almost free. The communication is virtually real-time, due to the connection overhead which is typically low.

The GSM/cellular based RTUs communicate with the base station using a phone line or wireless analog modem; therefore they have higher operating costs and are relatively slow due to the high connection overhead (up to one minute). Typically the taxation is made on a "per minute" basis. However, due to the general availability of the GSM network, the system is independent of the distance to the base station, thus regional and supra-regional networks can be easily built. Notwithstanding, the cost of running such a network can become significant.

Another solution is the use of GPRS (General Packet Radio Service) that is now a standard offering from most cellular network operators in the world. This solution still has the recurring costs issue, but this is far less of a problem as the taxation is based on the amount of data transferred, and not on a "per minute" basis. The connection overhead is low, in the range of several seconds. GPRS allows the use of the Internet protocols like TCP/IP and therefore large distances can be bridged virtually for free, including international communication.

The cellular providers, as well as the cellular terminal manufacturers are pushing the M2M paradigm, so there is momentum building behind GPRS, that in turn leads to substantial price reductions.

Base Stations

Base stations can be also of various types, in their simplest form they can be a piece of software running on a PC. Such a software downloads the data from the RTUs and stores it into a database, or in case of simple implementations, in files. More complex base stations consist of a separate wireless unit (or modem) and a storage unit that buffers data and delivers it to a PC over different types of interfaces, from serial to TCP/IP.

Base stations are generally difficult to justify to customers. For small systems (up to 10 RTUs) its cost becomes a significant part of the total investment; for large systems (over 100 RTUs) its performances and storage capabilities decrease.

The hardware and software developments costs, as well as the production costs, are also difficult to justify; as they are typically based on proprietary protocols, the units cannot be produced economically due in part to the relatively small quantities needed.

The fact is that in the early days of the telemetry the resources that could be built into an RTU were modest; in addition the PCs of those days were not reliable enough to run mission critical applications 24 hours a day. Clearly, there was an obvious need for a reliable product capable to operate flawlessly 24 hours a day, seven days a week, using battery backup in case of power outages—all in order to compensate for the small memory capacities of the RTUs combined with the weakness of the PC platform.

However, today the rules have changed: the RTUs have large amounts of memory almost for free (a typical RTU would store 30 days of data in a memory chip that costs now less than three Euro!), while the availability of low cost servers allows building very reliable, redundant 24/7 systems. All in all, it seems obvious that the receiver/base station concept is now obsolete and that alternative possibilities are already at hand. But more on this later.

SCADA Software

The data acquisition and control software (often known as SCADA software—an acronym for Supervisory Control and Data Acquisition) is typically the final destination of the sensor data. If also control functions are required, usually the same software sends commands to the actuators via the base station and RTUs, once the pre-programmed conditions are met (alternatively they may be operator triggered, i.e. manual operation).

There are many SCADA software solutions, but unfortunately most of them are either too simplistic and lacking in functionality, or overly complex and difficult to operate by non-technical users.

Very often developing such a software leads to high costs and low return due to the limited amount of customers. If the price would be right from the developer point of view, then probably nobody would buy the software. Therefore other methods must be envisaged to recoup the development costs, as e.g. increasing the costs of the RTUs. But how far are the customers prepared to go?...

M2M, a Disruptive Technology

The technological landscape of today changed a lot compared to what it was 10 years ago. For one thing, it is obvious that the wireless world is going through a consolidation phase. Beginning of the nineties there were almost no companies producing any form of OEM radio modules for telemetry. Now there are so many of them competing in this field, with margins that low that it is difficult to keep it a profitable business; mergers and acquisitions are the only alternative to becoming irrelevant.

On the other hand, several wireless standards established themselves: cellular (GSM and CDMA), Wi-Fi (IEEE 802.11a/b/g) and Bluetooth; with the recent approval of the Zig Bee standard (IEEE 802.15.4), it is unlikely that proprietary wireless solutions will still have significance in the medium term. All these developments strongly influenced the M2M development.

Accordingly, Metrilog's strategy was designed to fit the new conditions. This equates to the use of open standards and technologies, among them being the Internet and the GSM based wireless networks. Metrilog recognized the technological changes brought by the latest advances in wireless communication, as well as the Internet revolution; it embarked on designing and offering a series of services and products to help potential customers implement low cost, flexible, open standards based M2M applications.

M2M can be considered a disruptive technology because through the use of open standards it leads to systems from different manufacturers being interoperable, with a dramatic impact on the systems costs. This leads to a broader penetration of M2M applications into the people's lives.

On the following pages we will show how telemetry systems can be simplified by adopting Metrilog's M2M solution: we will revisit each of the basic components of a classic telemetry system first, and look at it through the light of M2M technology.

A Digital Approach to the Sensor/Actuator Issue

Metrilog is not manufacturing sensors/actuators, rather integrates them into its M2M system. The way the sensor/actuator integration is pursued is also a result of the quest for standards. The fragmentation in the sensor world is still important, and even though lately more and more manufacturers are offering digital, bus-based sensors, the analog sensors are still numerous. Metrilog uses a two-fold approach to this issue:

- Implement as many digital protocols as possible on its RTUs;
- Provide cheap sensor adapters, or even assist sensor manufacturers to bring their analog sensors to a digital bus.

As digital sensor bus of choice Metrilog focuses on an open protocol called SDI-12. This protocol went a long way from its initial publication: more and more companies announced, or are announcing products based on this protocol. The protocol is not perfect, but it's the only one that gained a larger acceptance in the sensor world. More about SDI-12 can be found at http://www.sdi-12.org.

Other protocols are also envisaged, e.g. Modbus, CAN, and others, depending on applications.

As a result of Metrilog policy regarding sensors/actuators, there are important advantages that extend to other parts of the system, notably the RTUs:

- The system can be easily customized for a specific application; a standard data logger usually has lots of different inputs in order to accommodate different analog interfaces (4-20 mA, 0-1 volt, 0-10 volt, pulse counter, serial, etc.), while in this case only the specific interfaces required by a certain application are used. Benefit: lower cost.
- Some of the complexity is moved out of the RTU into the sensor or the individual interface module (e.g. a 4-20 mA converter). Benefit: lower cost of the RTU.
- Long cables (up to 60 m) can be used, if needed, allowing the connection of multiple sensors to the same RTU. Benefit: simple installation and lower cost.

Metrilog is offering its SDI-12 expertise to any sensor manufacturer that wants to convert their analog sensors to a serial bus output.

The Metrilog's T707 RTU Platform

Given the above assumptions, the structure and design of an RTU are relatively straightforward. In what the wireless communication path concerns, there are currently only two viable alternatives:

- Proprietary radio;
- GSM/GPRS based.

In the case of a proprietary based radio solution, the choice must be made between the 70 cm band and the 864/916MHz LPD/ISM band. For medium range solutions (10 to 30 km), the 864/916 MHz band is not particularly appropriate, additional efforts must be made to increase the receiver sensitivity in order to compensate for the increased attenuation/absorption at these frequencies. This in turn will increase the complexity and the costs. But, these bands have the advantage they can be used for free.

The lower frequencies (70 cm band) are more appropriate for relatively long distance radio communications. However, due to so many different radio regulations throughout the world, too many different versions must be designed and manufactured, thus adding the cost of certifying and supporting them. In addition, very often the use of these frequencies is not for free.

Good performance cannot currently be attained with simple, one chip based solutions; the consequence is that the design of such radios is relatively difficult and the cost is high. But the most dramatic effect is the lack of components: classically designed radios are the exception nowadays, therefore more and more chip manufacturers are discontinuing electronic components that are essential for such designs.

A GSM/GPRS based RTU solution solves most of the problems shown above. Metrilog decided early during the design phase of its services offering that this is the most cost effective way to implement a universal, flexible M2M solution; therefore it choose the GPRS based T707 as its main RTU platform. The advantages are compelling:

- GSM/GPRS modules are relatively cheap, and this tendency will continue. Paradoxically even though they are more complex, these modules are cheaper than the proprietary radio modules: the number of modules currently manufactured is huge compared with those of proprietary radios, thus the low cost.
- Higher throughput: a GPRS based T707 RTU reaches transmission speeds of up to 50 kbps, sometimes more (depending on the cellular provider's network and the module itself). This compares very favorable to the potential 9.6 kbps attainable with standard radios (typical for reaching a 20 km communication distance).
- No need for a base station: as T707 RTUs implement a TCP/IP stack, they can communicate either directly or indirectly with any TCP/IP capable SCADA software. The increase in transmission speed, as well as the on-board memory of the RTUs, both render the receiver/base station concept obsolete. As an example if the SCADA software would be down for a week, to retrieve the accumulated data from a T707 RTU would take only approx. 30 seconds.
- There are no distance problems and no routing stations are required; regional, supra-regional and even international networks can be easily built. The only condition is that GSM cellular coverage is available at the installation sites.

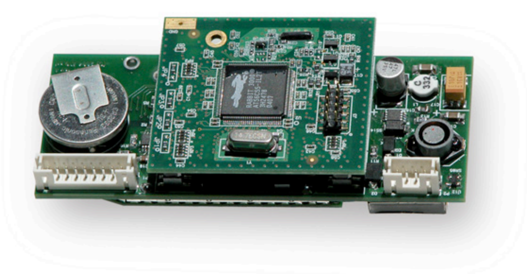

Fig. 2. Board level T707 RTU

There are currently several implementations of the T707:

- Board level to be embedded into OEM equipment;
- Standalone IP66 box.

A DIN rail version is also planned and will be soon available.

The T707 RTU is a general purpose, open device that can be used for data collection, logging and transmission for a large array of applications, e.g. vending, metering, environmental measurements, security, asset management and location, and many others.

From the design phase it was required that the amount of development be kept to a minimum, especially from the hardware point of view. As a result, most parts (including sections of the software) are ready made, off-the-shelf components. The GSM module and the microprocessor core, as well as software libraries and the Real Time Operating System are such off-the-shelf components embedded in the final design.

The use of the cellular networks is associated with operating costs. However, there are more and more affordable offers specifically adapted for M2M and telemetry applications. The packet oriented pricing model is particularly advantageous for telemetry applications because the amount of data transfered is relatively low.

Fig. 3. The T707 RTU as a standalone unit

The communication protocols employed are specifically designed to reduce the data traffic. Metrilog uses WAP (Wireless Access Protocol) over UDP to reduce the headers of the IP packets to a minimum, and in order to further compress the amount of data without compromising the flexibility of the system, WBXML (Wireless Binary XML) document based RPCs (Remote Procedure Calls) are used for data interchange.

The T707 platform accepts only digital sensors. The main protocol is SDI-12, which is available both native and over an RS-485 interface: the operating mode can be switched in the field by means of an internal jumper. Additional bus protocols can be implemented on request.

The power consumption of the T707 devices is extremely low. This is particularly important for applications in remote areas where electrical power is not available. For such cases Metrilog offers a special solar power supply unit with solar panels starting at 2.2 W of output. There are different operating modes, but the power consumption may go as low as 15 mW average while the unit is still ready to receive requests over SMS or data calls.

All configuration parameters e.g. number and type of sensors, sampling intervals for each individual sensor, connection intervals, and many others, are stored as attributes in the internal structures of the T707 RTU, and all of them can be changed remotely via the Internet (more about this later). Even the firmware itself can be updated over the air (OTA).

There are two levels of power failure protection: all configuration parameters are stored in a battery-backed memory, but in addition the most important parameters, like those essential for assuring the connectivity via GPRS, are additionally stored into non-volatile memory (EEPROM).

The data logging functionality of the T707 RTU implements a large circular memory storage capable of keeping more than 50'000 data points. This storage is also protected against electrical power loss by means of a backup battery. The data points are stored and retrieved based on their time-stamp. The internal real time clock is Daylight Savings Time aware and is periodically synchronized over the Internet (typically once a day).

T707 Platform Specifications

Parameter	Value
GSM/GPRS	900/1800 MHz
Interfaces	RS-485, RS-232, SDI-12
Supported protocols	TCP/IP, WAP, XML, WBXML
Internal storage	256 Kbytes, non-volatile (over 50'000 data points)
Sampling interval	Programmable (minutes, hours, days, weeks)
Power supply	External, 5.5 to 20 Volt
Power consumption	Standby, receive: avg. 1mA (at 12 V) Transmit max 200 mA (at 12 V) Absolute maximum 600 mA (at 5.5 V)
Operating temperature	-20ºC to +60ºC
Dimensions	110/75/55 mm
Weight	400 g
Environmental protection class	IP66

Metrilog's M2M Gateway Concept

By now, it becomes obvious that the question "Do we still need a base station?" deserves a negative answer. However, it seems there is a missing link between the RTU and the SCADA software, isn't it? Indeed. The answer is: the missing link is the "the virtual receiver"!

Imagine that instead of each user having its own (expensive!) base station, it simply leases an Internet based, software receiver from a centrally managed point. As it has been shown earlier in this paper, today the reliability of a well managed server is more than sufficient to assure a 24/7 service. Such a server can replace hundred and thousands of base stations!

This concept is particularly suited to GPRS based RTUs: due to factors like the dynamic IP addressing, use of firewalls by GSM providers, etc., only the RTU can normally initiate a connection. But this connection must be done to a fixed IP address on the Internet. On the other hand, it is very likely that the customer's SCADA software is also situated behind a firewall and most probably has either a dynamic IP address or worse, a private IP address that cannot be routed over the Internet. Therefore without an IP "meeting point" in the middle, a connection between the RTU and the SCADA software is impossible.

Enters Metrilog M2M Gateway: a service offered by Metrilog that solves many traditional telemetry issues:

- Assures the connectivity to the RTUs as they periodically connect over the Internet to the M2M Gateway;
- Keeps the configuration of the RTUs and passes it any time they need it (e.g. after a cold reboot) or anytime the user changes parameters;
- Assures the authentication of both the users and the RTUs;
- Manages a circular storage with RTUs data—an additional backup; the amount of data kept as backup depends on the customer requirements;
- The M2M Gateway offers the customers a single point of data collection for all their remote devices, no matter where they are located;
- Offers independency from structural and protocol changes on the chain between RTU and the customer's application;
- Relieves the customer from understanding the basic concepts of the Internet, or obtaining a fixed IP address for making his server available to the world;
- The customers are not anymore confronted with an intimidating software: they will access their data whenever they want, wherever they are, via the Internet by using a standard web browser;
- Using standard Internet based protocols as XML-RPC, SOAP, Web Services, etc. the M2M Gateway provides the RTU data to the users' SCADA software.

There is of course the issue of the SCADA software itself. Generally, the development costs associated with this kind of software are high and difficult to recoup. To make things more complicated, many customers have their own software, and they need only the sensor/actuator data transported out of, or to the telemetry site.

The M2M Gateway paradigm provides the ideal solution to these problems, because it insulates the protocols from the data itself. Different incoming protocols used for data transmission between the RTU and the gateway can be translated into different outgoing protocols used between the gateway and the user's SCADA software. Apart from standard, XML based data transfer protocols, additional protocols may be developed/implemented on Metrilog's M2M Gateway e.g. for legacy SCADA software, upon request.

The M2M Gateway is structured on *realms*, that is, each user has his own realm. A realm represents all the resources accessible by a certain user: areas, RTUs, sensors, actuators, sensor data and so on. There are several privilege levels for each user: some users may have the right to perform administrative tasks on a given realm (e.g. add/remove RTUs and sensors/actuators, reconfigure RTUs, add/delete users, etc.), while other may only be able to examine the data.

In addition to basic M2M services, as an option Metrilog offers also Web based application services. Separate application servers are used to implement these services. The processed results can be offered via the Internet, WAP or SMS services.

The complete picture of a telemetry system looks now different:

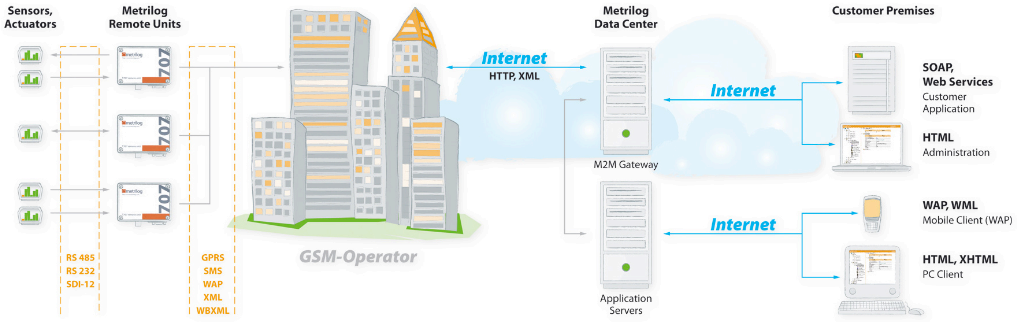

Fig. 4. An M2M based telemetry system

Often, the question arises why should a customer use Metrilog's services, and not install an M2M Gateway at his premises? A relevant answer is cost. Metrilog is running the M2M Gateway services for a large number of customers, thus the costs associated with running the data center, redundant servers, Internet connection, maintenance and backup, etc. are divided to a very large number of RTUs and customers. If a customer has only a couple of hundreds of RTUs, running his own gateway is simply not cost-effective. A user is simply outsourcing his telemetry/M2M needs to Metrilog which has the capabilities and personnel to keep those servers up and running.

Another reason is the fact that Metrilog improves and extends constantly the M2M Gateway software; that would translate in upgrade, or maintenance costs for customers running their own gateways, something that regular customers using Metrilog services do not have to pay.

The reverse notification channel is assured by either sending an SMS, or by issuing a short data call to the RTU. All this is automatically and without any additional costs handled by Metrilog's M2M Gateway. Due to special arrangements with the GSM providers, Metrilog is able to send thousands of SMSes per month without having to worry about their costs.

GSM/GPRS Data Services

An important part of Metrilog's business model is represented by the arrangements with the GSM wireless providers. It is very important for the customer to have a clear view of all the costs associated with his M2M system, without hidden costs. Metrilog offers the complete service: the sensor/actuator data from/to the telemetry site, to/from the user's premise—everything on a single invoice![3].

Naturally, this must also include the costs associated with the data transfer over the wireless infrastructure. As mentioned earlier, the arrangements that Metrilog has with the wireless providers (e.g. SMS and bulk data transfer) results in a very low price per used megabyte. This in turn translates into low rates for Metrilog customers, e.g. typically 10 € per month per remote device for an average application using some 10 MB per month. There are no hidden costs, that is, the SIM card costs, data transfer costs, use of the M2M Gateway services, occasional back-channel SMSes, all this is included in the 10 € monthly subscription. For applications with lower data transfer requirements, it may be even less.

3 The customer's Internet service is however not included; an Internet Service Provider is required

Conclusions

M2M brings to the world of telemetry discipline, accessible solutions, and open standards. As a strong believer in open technologies, Metrilog offers a complete end-to-end, standards based M2M solution.

There are many applications that can benefit from Metrilog services, just to name a few:

- Vending machines;
- Road traffic control;
- Remote resources utilization, remote metering;
- Fleet control (in connection with GPS location modules);
- Security;
- Home automation (e.g. control remotely devices at home when in holidays);
- Control of HVAC systems in large buildings and industry;
- Agriculture, precision farming;
- Irrigation systems;
- Environment monitoring and control, alarming;
- Etc.

Due to the technological advances in the last years, Internet and especially wireless Internet will become more and more common-place. The massive penetration of Wi-Fi based devices and mobile telephony accelerated the trend towards mobile Internet: the portable phone, the PDA and the computer are merging. People will want to be able to check on the road what's going on at home or in the office. M2M is a technology likely to have a big contribution to this development that will lead in return to a great new number of services and applications being available from mobile operators. Metrilog is poised to become an important player in the M2M market.