

## Parking Lot Gets Smart with ZigBee



### Chaos Underground

Nowadays, the underground parking lots of office buildings and shopping malls are sprawling, multi-level compounds. Finding a vacant parking spot in these labyrinthine catacombs has become a non-trivial task, if not an outright challenge. As precious minutes tick away, beleaguered drivers circle the lot, growing increasingly frustrated at the lack of parking spaces. At best, these searches are an inconvenience; at worst, they can cause you to be late for a critical appointment, or even miss it entirely. In a situation like this, you wish somebody (or something) could just guide you to a free space. Save for valet parking, this luxury has never been an option. That is about to change.

According to various studies, average time spent cruising for a parking space in urban public parking areas varies from 3.5 to 12 minutes, with distance traveled ranging from a half mile to over a mile. It may not seem like much, but with few hundreds square meters of parking space, and a turnover rate of 10-15 cars per space every day, even a small amount of cruising time per car adds up to a lot of traffic. Not to mention wasted gas and unnecessary air pollution.



**Innovative  
Technologies**

### Innovative Technologies - Focused M2M Solution Provider

The European urban population has to struggle with underground parking lots and related challenges on a daily basis. Paris-based hi-tech startup Innovative Technologies SARL singled out this arena as a prime application area for automation. The young company already boasts an impressive portfolio of services catering to a wide range of applications; from security and safety to access control and building management systems to optimization of industrial processes. With a strong focus on the business benefits that new technology will bring to customers, Innovative Technologies' expertise encompasses, but is not limited to, hardware design, software and firmware development. Wireless technologies have always been an area of interest for the company. Already possessing expertise in RFID, Innovative Technologies recently broadened their portfolio with ZigBee, an up-and-coming standard for wireless sensor monitoring and control.

## Picking Right Technology

The automation process requires placing “smart” detection sensors next to the parking spaces throughout the parking lot. The sheer size of an average underground parking lot ruled out running wires to each sensor right from the start. Besides the apparent potential technical difficulties, the cost of wires easily runs up to a prohibitive level of over €200 per meter. Going wireless was an obvious solution.

The next challenge was to select the right wireless protocol; there are a considerable variety of both standards-based and proprietary wireless solutions available. Standards offer clear benefits, such as interoperability and vendor independence. Among available wireless standards are Bluetooth, Wi-Fi and ZigBee. One of the critical requirements, due to the concrete walls and pillars in a parking lot, was a self-healing multi-hop mesh network, capable of re-routing a signal if line-of-sight is blocked. Another important factor was that the wireless devices were battery operated, which placed severe limitations on power consumption characteristics. Presently, only ZigBee, a low-power standard for mesh networks, based on IEEE802.15.4, can meet both criteria. So the choice was made in favor of IEEE802.15.4/ZigBee.

## Partnering with ZigBee Technology Provider

The next step was to select a ZigBee platform. At project launch, Innovative Technologies had to make an immediate decision whether to go with a chip or a module hardware platform. A number of leading semi-conductor manufacturers, such as Atmel, Texas Instruments, Freescale and more, offer both microcontrollers and radio transceivers. Some vendors also make so-called “systems-on-chips,” or single chips, that combine both MCU and RF chips.

While chipset costs less than a module, there are hidden costs associated with integrating it into the product design. Unlike chipsets, modules already contain all the design related to RF/MCU, with all required circuitry and antenna added. In addition, modules can be easily mounted on a PCB—enabling greater flexibility, time and cost savings during the design and prototyping phases. No RF expertise is required. Another benefit is that modules normally come with RF certification approval, which is transferable to the end product. Generally, the rule of thumb is if a product is mass produced in quantities well over 100K, then using chipsets can be cost-efficient. Otherwise, modules are clear winners.



IEEE802.15.4/ZigBee Module with Chip Antenna

For Innovative Technologies, ZigBee modules were an intelligent choice. Searching online, Innovative Technologies found a number of vendors offering 802.15.4/ZigBee modules. Two module characteristics were of key importance: power consumption and size. The sensor device has to work autonomously for 4 years on one 9V battery. Plus, the PCB board had very little “real estate” left for module integration. Most of the leading ZigBee modules boast very low power consumption. However, when it comes to size, only the ZigBit modules from MeshNetics—featuring a tiny footprint of just over three square centimeters—met Innovative Technologies’ requirements. The fact that ZigBit modules come bundled with the MeshNetics’ own ZigBee networking stack software, along with support for both hardware and software, further boosted Innovative Technologies’ confidence in their choice.

## ZigBee-Based Wireless Sensor Network

The next step was to try out the ZigBit modules. Innovative Technologies ordered the ZigBee Evaluation Kit from MeshNetics to achieve this goal. Containing three ZigBit-based development boards with sensors, accessories and software, the kit provided sufficient tools to evaluate the module's performance, ensuring that it lived up to expectations. After a successful test run, Innovative Technologies began prototyping their application.

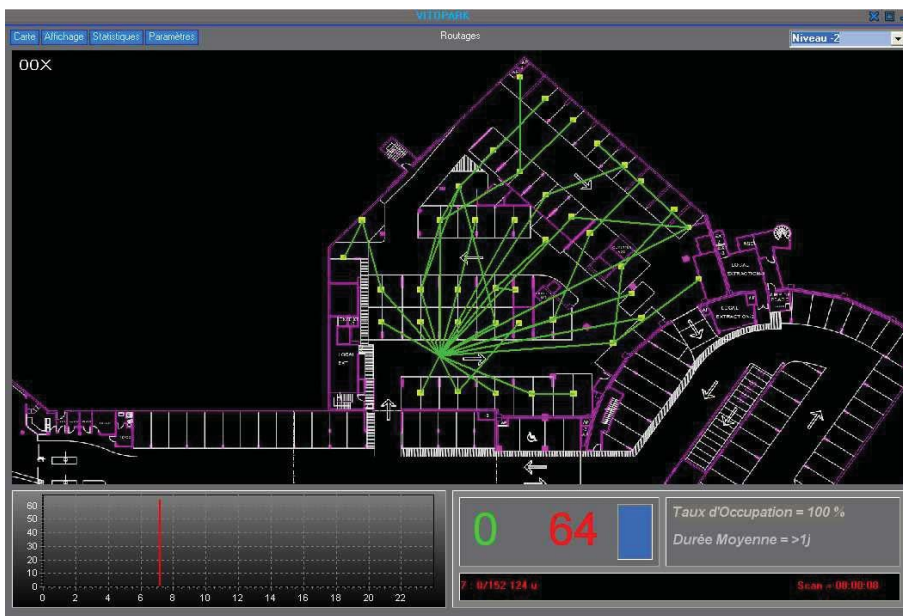
ZigBit modules featuring dual chip antennas are integrated into boards connected with a range finder sensor and 9V battery. ZigBit modules take full advantage of the new Atmel's RF transceiver AT86RF230, which possesses -101dBm of Rx sensitivity and up to +3dBm of Tx power. This combination is known as the "link budget." Range of operation is a logarithmic function of link budget, so a difference of only 9 dBm nearly triples the range. Thanks to the outperforming link budget, the range of AT86RF230 is almost 3 times that of any other 2.4GHz 802.15.4 radio on the market today. This is important in a spacious parking lot. If a module provides a good range, it means that one sensor device can be used to cover several spaces. Besides, the parking lot environment, with its concrete walls, pillars and metal cars, is not exactly an RF signal-friendly place--making strong RF performance a must for the modules.

Thanks to the embedded mesh networking stack software, the ZigBit module-based sensor devices form a self-organizing, self-healing network. Most of the time, the devices remain in sleep mode, saving the batteries. The devices wake up every minute for a few milliseconds to take measurements, and then go back to sleep. A ZigBee network normally has three types of nodes: end devices, routers and coordinators. The end devices, featuring sensors, collect the data which they then transfer on to a coordinator. In case a coordinator is located too far for a direct link, the routers are used. In Innovative Technologies' project, the relative compactness of the parking lot and strong RF performance of the ZigBit modules eliminated the need to use routers. The sensor data from the end devices is transmitted within the network on to a coordinator. The coordinator serves a gateway, transferring data to a central server. This can be accomplished either directly or via GPRS gateway serving as an intermediary. The entire data collection and flow process is fully automated

## Automating Parking Lot

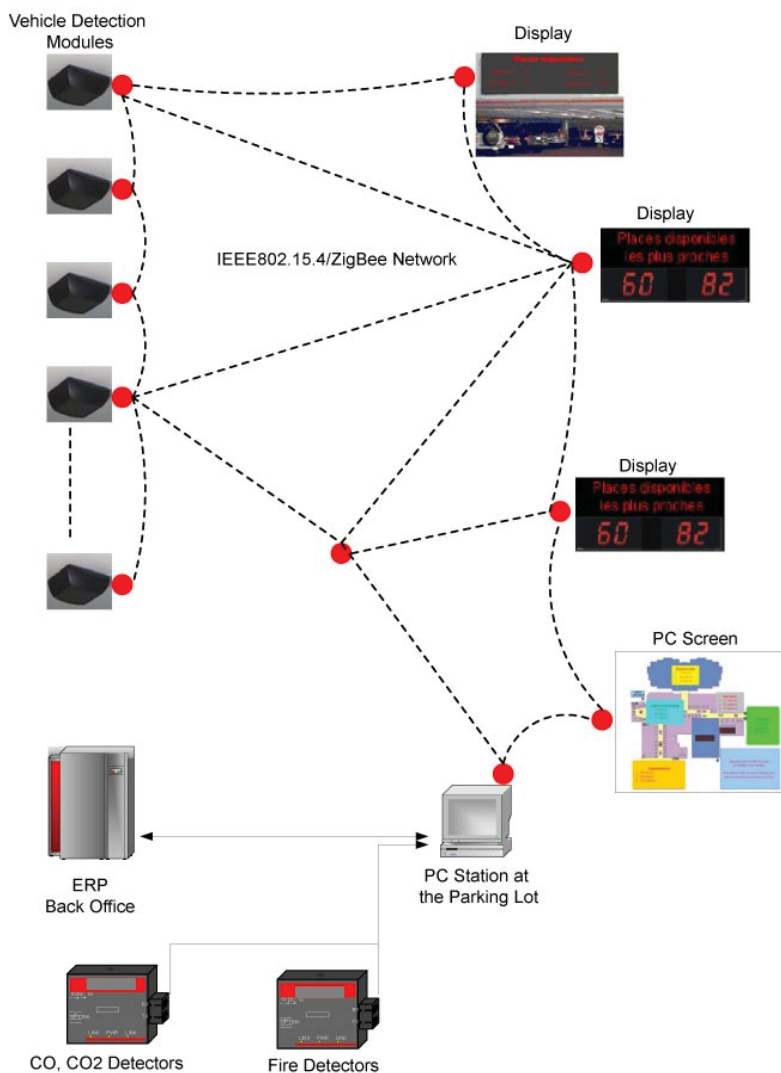
Innovative Technologies selected one of their client's underground parking lots for a trial deployment. The parking lot automation system, called "E-Park", comprises of the following components:

- Vehicle Detection Modules (VDMs)
- Info Displays
- Data Management Software
- Gateway to the Back Office



ZigBee Network Topology View

## SYSTEM'S ARCHITECTURE



Vehicle Detection Module



Auxiliary Display



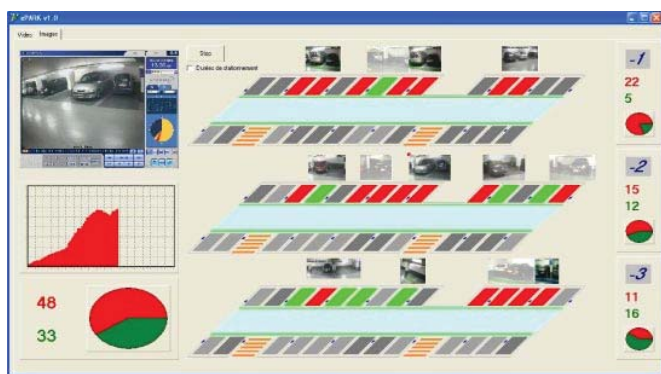
Display at the Entrance

Vehicle Detection Modules (VDMs) are mounted on the ceiling right above the parking spaces, or on the walls. The trial setup was with one VDM monitoring two parking spaces, although the tests showed that a single VDM can efficiently monitor up to four parking spaces. Each VDM is powered by 9V battery allowing for 4 years of autonomous operation. Inside every VDM unit is a ZigBit 802.15.4/ZigBee module, enabling it to communicate with other VDMs and form ZigBee network.

Compact displays serve to communicate the useful information to a driver, such as a number of available parking spaces and the number of the closest free spot.



Data Management Software visualizes the graphic map of each parking level, so that an operator can see in real time which spots are taken and which remain free. The software also displays the current number of free spots, the parking lot filling trend, and an average turnover rate for both individual parking spaces and the entire parking lot. The system generates alerts when the parking lot is almost full, when a "parking space hogger" is detected, when the temperature exceeds the set threshold, or when the unauthorized vehicle movement takes place. Besides being displayed on a PC screen, the alerts can be broadcast to PDAs and cellular phones as text messages. An operator can set up the system's various parameters. The system keeps the data logging, and the historical statistics can be accessed for further analysis. Remote operators can access the system via the web.



System Operator Interface



Data Analysis Tools

## Parking Can Be a Breeze

Until now, you would be taking a big chance when you entered that parking lot, and risk having to cruise for a while before finding a free spot. Now, after the MeshNetics ZigBee-based WSN deployment, you will find that the previously frustrating parking lot experience has pleasantly changed. Right at the parking lot's entry, you will be greeted by a large display clearly showing the number of available spaces on each level with a separate number indicating spaces for the disabled. After making sure that there are spaces available, you proceed to a toll booth where another display repeats that information and recommends the closest free spot. As you enter a level, a smaller display repeats the parking space number previously recommended, or suggests a new one, if it was already taken. As soon as you park in the suggested spot, the system shows that space as occupied. When you leave, the system updates the information right away, so that other drivers can use the space. Finding a free spot can be an easy and stress-free task after all!

Below is the summary of the benefits that the ZigBee-based E-Park system has to offer to both the parking lot operators and the drivers:

### Parking Lot Operator Benefits:

- Real-time parking lot occupancy information
- Improved space utilization
- Faster vehicles' turnover rate
- More efficient and safer traffic flow
- Valuable statistics
- Parking usage trend analysis
- Added value services for clients

### Driver's Benefits:

- Significant cruising time savings
- Guided assistance in finding a free space
- Audio assistance
- Displays catering to the disabled people's needs
- Lower fuel consumption
- Reduced carbon dioxide emissions
- Less frustration

## Let the Numbers Talk

As a direct result of the implementation of the ZigBee-based system by Innovative Technologies, the average cruising distance was reduced by 30%, while time to find a free space and park was reduced by 25%. This led to increased vehicle turnover and a better occupancy rate, which noticeably added to the parking lot operator's bottom line. And that's not to mention that the drivers can now avoid all this unnecessary stress, and will be more likely to return to this parking lot in the future.

### In the Words of Innovative Technologies:

"It was clear from the start that the wireless was a way to go," said Mr. Philippe Besnard, CEO of Innovative Technologies. "We wanted to provide our client with a reliable standards-based solution, which determined our choice of ZigBee. We selected few ZigBee platforms from various vendors, and then put them through rigorous testing. Functionality, power consumption and overall cost of the monitoring system that we designed had to conform to tough criteria. MeshNetics ZigBit module emerged the winner. It not only had a very low power consumption and superior radio range, but was much smaller than its peers. The latter mattered to us, as the board space was at a premium. Finally, we were pleasantly surprised with the quality of support, and professionalism of MeshNetics team. We look forward to building on this foundation, and continuing our cooperation in the future."

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