# Demo Abstract: An Environmentally-Powered Wireless Parking Guidance System for Open Car Parks


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## 1 Introduction

In densely-populated urban cities, motorists often face the problem of searching for parking lots for their motor vehicles. On arriving at their destinations, motorists often have to drive around trying to find an available parking lot, causing much frustration, and wasting time and fuel consumption. In some buildings, indoor carparks provide useful information such as the number of available carpark lots, as well as overhead lights guiding motorists to available carpark lots. However, such a system would be very costly to implement in an outdoor carpark, due to the cost of infrastructure and wiring.

On the other hand, outdoor carpark spaces provide a potential for deploying carpark monitoring application based on environmentally-powered wireless sensor networks (EP-WSN). Making use of wireless communication technology reduces the cost in wiring large spaces, and benefits from multi-path communication for increased data delivery efficiency. Powering such sensor nodes by renewable energy sources such as solar energy allows for perpetual operation, with an energy storage buffer that caters for night-time operation, or during periods of low sunlight availability.

In this demonstration, we implement and deploy an EP-WSN in an outdoor carpark to provide parking guidance to motorists. The system diagram for our demonstration is shown in Figure 1. We will demonstrate a wireless sensor network that exploits multi-hop wireless and ambient energy harvesting technology to provide low-cost, real-time, sustainable and eco-friendly monitoring of outdoor carparks. We make use of solar energy harvesting sources to power our vehicle detection sensors. Upon detecting the presence of a car, this information is transmitted via a multi-hop wireless network to a base station, before being forwarded to the central server for information dissemination to motorists.

Unlike current outdoor carpark monitoring systems where sensors are battery-powered and can only communicate with mobile or fixed base stations, such as patrolling carpark attendants or parking meters, our sensor nodes are powered by energy-harvesting sources, and they can communicate with one another in a multi-hop configuration.

Since the number of sensors and communication devices scales with the car park size, our proposed system is expected to significantly reduce maintenance cost, such as by avoiding the costly process of battery replacement, and also reduce environmental impact, for example, through more effective car park guidance and reduced reliance on batteries.

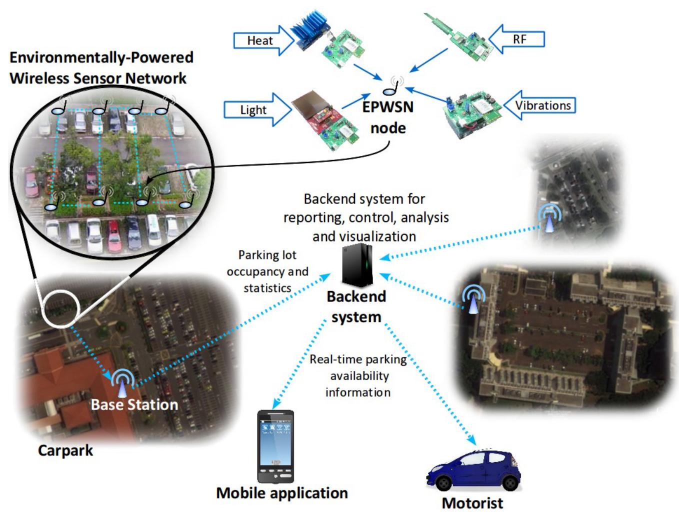


**Figure 1. System overview**

The main objectives of our system are to develop networking protocols and duty-cycling algorithms, while making use of multiple existing sensing and harvesting technologies, to achieve energy-neutral operation towards a viable deployment for a real-world carpark monitoring application.

## 2 Energy-aware Sensing and Communication

In traditional battery-based communications, device operation attempts to minimize energy consumption to extend network lifetime. With energy harvesting, rather than minimizing energy consumption, the sensor nodes attempt to optimize the energy consumption subject to environmental conditions, such as harvesting rate.

The key enabling technology for our system is energy



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harvesting capability, allowing for perpetual operation of devices in an untethered manner. The main contributions of our system are as follows:

1. To implement an adaptive duty cycling algorithm that balances energy harvesting and consumption rates, with the objective of achieving energy-neutral operation;
2. To design and implement a multi-hop networking protocol with varying duty cycles.

The wireless sensor network is designed to be energy-aware and all modules, from routing to sensing, actively use energy availability information to adjust their activity to achieve energy-neutral operation [2]. When there is more sunlight, nodes increase their level of activity, thereby improving performance, and maximising utilisation of excess ambient energy which would otherwise be wasted. This is particularly desirable for a carpark application since traffic flow in carparks are expected to be higher during the day, when more ambient energy is available, than at night, when no ambient energy is available.

We use an adaptive duty-cycling algorithm [3] for this purpose and implement an energy-aware routing protocol and sensing algorithm which use information from the algorithm to determine their operational behaviour. The routing protocol is duty-cycled; when nodes are active they listen for data packets from other nodes and forward them to the sink using opportunistic [1] techniques. The duty cycle adapts to higher ambient energy by allowing the node to stay active for a longer period, which results in a more potential forwarders being active for any given transmission, and in turn reduces both the total number of transmissions (which might cause self-interference to upstream nodes) and end-to-end packet delays.

The sensing algorithm polls an ultrasonic sensor for a distance measurement periodically and maintains a sliding window of previous readings, putting the readings through a mode filter before deciding on the parking lot occupancy status. A higher duty cycle increases the polling frequency and makes the algorithm more responsive to changes in the lot occupancy.

The key enabling technologies behind our system — energy harvesting, opportunistic routing and adaptive duty-cycling — have been studied at some length; however we are the first to integrate these ideas into a working system for carpark monitoring.

## 3 Demonstration details

**Figure 2. Wireless sensor node**

In this demonstration, a wireless sensor network comprising 10 nodes will be deployed at an open air carpark in Singapore. Each node (Figure 2) comprises an ultrasonic sensor, Arduino-based microcontroller platform, XBee radio, and solar panel. A base station collects occupancy information from the network and the data is relayed to a back-end server for processing, before being displayed at the demo booth (Figure 3). We will highlight two key components of our carpark monitoring system:

1. **Node demonstration:** Each node uses an adaptive duty-cycling algorithm, such as in [3], to tune its own duty cycle according to energy availability. We demonstrate the effects of (i) varying incident light intensity on the node's duty cycle as well as the sensing rate of the ultrasonic sensor, and (ii) different harvesting rates on the delay in detection of state changes.
2. **System demonstration:** We show the operation of our energy harvesting WSN nodes deployed at a real-world carpark in Singapore. Information from the sensor nodes is sent to a gateway node, which forwards it to a back-end server. Figure 3 shows a client application which communicates with the back-end server to display carpark lot availability information. We have implemented client applications on desktop and mobile platforms, as well as a Java applet within a Web browser. We also demonstrate the accuracy of our sensing algorithm by displaying a live video stream from the carpark for viewers to compare our application with the actual real-world carpark occupancy.


**Figure 3. Demo booth**

## 4 References


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