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PLUG: A ZIGBEE NETWORK FOR PLAYING UBIQUITOUS GAMES

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ABSTRACT

In this paper we present the project PLUG (PLay Ubiquitous Game and play more) the aim of which is to deploy a ubiquitous game in a museum. For this, we required wireless communication between players and the game server, and the deployment of a wireless sensor network for monitoring the physiological activity and movements of the players. Among potential technologies, we selected zigbee. Here we describe the project and the challenges of devising a cheap and useful wireless network solution, including our experiences dealing with hardware and software issues. This work can be used as a reference for future game projects.

KEYWORDS

Ubiquitous, pervasive, video game, wireless sensors network (WSN), physiology, mobility, entertainment.

1. INTRODUCTION

With video games, we can produce feelings of immersion in a variety of ways, but it is interactivity that differentiates video games from passive activities. Voluntary actions of players are already fairly well integrated through human machine interfaces (e.g. keyboard, Wiimote). Non-voluntary actions, however, such as physiological or emotional variations, are just beginning to be studied.

The Plug Project - PLUG (PLay Ubiquitous Game and play more) studies the use of embedded and mobile technologies for building pervasive and ubiquitous games, as well as player acceptance of such games from socio-cultural, economic and industry points of view.

The Cnam museum *(Museum of Arts and Crafts)*[1] was open to innovative ideas for attracting children and teenagers. Our choice of a pervasive game[9], inspired by the game "Happy Families", was a natural fit, that one enriched with puzzles. In this game, players collect cards pertaining to the four families of museum objects. Using the NFC facility of a mobile phone, players collect virtual cards representing real objects of the museum. The virtual cards (RFID tags) are located near the real objects chosen for the game. The virtual universe of the pervasive game is filled with animated objects with their personalities attributed to them by their inventor. Once they are removed by the player by moving a real object moved toward a phone and vice versa, the player hears a text that provides feelings and emotions related to the inventor or to the object itself. The game is also competitive since the game's winner is the team player that gets the highest score within a 55 minute game session.

To ensure the project's success, mobile telephony, WIFI, Bluetooth, RFID were studied. Our main concern was the design of pervasive games using wireless technology. In this context, the use of traditional interactions is difficult due to movement. We used physiological monitoring as a means to interactively adapt the narration to the emotional state of the player using "embodied" sensors that monitored heart rate and activity level.

The project included ten academic and industrial partners. In addition to the completely autonomous WSN described hereafter, the game exploited two other technologies: RFID to collect objects, and mobile touch screens needed for player interaction. For want of a single communication system that could manage both these elements, we used GSM NFC and the iPod touch™ systems connected via Bluetooth. Communication between the game server and the gamers used both these systems.

[1] http://www.arts-et-metiers.net/musee/visitor-information

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In order to detail the physiological state of the player, we attempted to retrieve, analyse and transmit the physiological player's data to the game server. This was in order to modulate game situations by modifying the narration in real-time. The player's state has an impact on the rules of our game. The game's behaviour was changed by a human game master or an algorithm. In order to collect physiological signals that could play an important part in the detection of emotion, we created and/or used various sensors: accelerometer for the movements, electrocardiogram (EKG) to compute the heart rate, temperature, breath rate, galvanic skin response. In practice, only the accelerometer and the EKG were integrated in the final game design because the temperature signal suffered from inertia, which made it useless in our context. The breath rate signal was too noisy, due to the permanent motion of the player, and the galvanic skin response sensor appeared to be disturbing the game device handling.

Sensor - Sensors are connected to the analogical inputs of the microcontroller, reading values in the form of electric potentials and converting them into numerical values, filtering those values if needed, and concatenating them and constructing a message which is sent via a serial port. The connected radio module transmits the message which is conveyed through a WSN to the central server. The game is managed on the server using an adaptability engine that takes into account the physiological values received. The process allows us to obtain the physiological state of a player within a few milliseconds.

Our work relates to manufacturing and operating the various sensors were described in previous articles[1, 2]. This project focuses on the WSN transmission of physiological signals sensed on a free and moving player.

In order to minimize load, the network transmitting the physiological signals needed to be independent from the main network of the game. The major difficulty came from the institutional context of the game's location. It was formally impossible to install equipment for two reasons: architectural (the buildings are old and protected) and, regulation and safety. The challenge can be summarized in the deployment of a WSN that covers all the rooms involved in the game - around 6000 m^2 - with light and invisible installation.

In this rest of this paper, we review the literature on pervasive games then compare wireless technologies and describe the various zigbee implementations and the experiment in section 3. We conclude with a summary of our contribution.

2. STATE OF THE ART

Ubiquitous computing lead to an increase in work on pervasive games. In Memoriam[3] game (2003) was one of the first attempts to expand the boundaries of a game. Intriguing messages (SMS, emails) could be sent by the game server, any time regardless of the player connection. The line between the game and daily life (the border of the magic circle) became uncertain. Human Pacman[4] (2004) breathed life back into the arcade game from the 80's, by replacing the mazes and characters with real urban areas and humans. Each player had a mobile phone and was geo-localized. The European project Iperg[5] (Integrated Project one Pervasive Gaming, 2004-08) offered three different toolkits (augmented reality, mobile telephony and ubicomp), making it possible to deploy a pervasive game. The project also originated several pervasive games developed with these tools. MYHT[6] (2008) took up the idea of the city as playground: around ten players find their twin partner, according to their cardiac rhythm. Each player was equipped with a mobile phone and a heart rate sensor communicating via Bluetooth. In other works, one can see technologies with shorter range like Bluetooth or zigbee: either the environment is more constrained (interior only), or the requirement is only the replacement of a wired connection (point-to-point), Liu and Ma[7] or Borriello and al.[8]. Overall, the popular networking technologies for the development of pervasive games remain Wifi and GSM, for covering indoor and outdoor environments.

In the following sections, we present our experiment in which a zigbee mesh was deployed to monitor the players in real-time and thus to provide in real-time information to the game engine.

3. UBIQUITOUS NETWORKING

Although there are many options for wireless technology (see Table 1), player mobility necessitates a flexible wireless technology involving roaming and routing. RF and Bluetooth are more dedicated to peer to peer (*ad hoc*) networks and were therefore bad choices. GSM, WiFi and ZB remained as candidates. ZB was the best choice, for cost, and power consumption, as well as other factors not mentioned in Table 1: hardware size, electronic integration and ease of use.

We have two types of zigbee modules, manufactured by Digi (formerly Maxstream): XBee series 1 (XBs1) and XBee series 2 (XBs2). The low electricity consumption of this equipment makes it an ideal candidate for embedded applications. The main difference the two models lie in the capacity of XBs2 to provide multi-hops routing capabilities, XBs1 offering only short range point-to-point or broadcast connections.

Table 1. Wireless devices comparison

Type	Range	Data Rate	Cost	Energy	Interface
GSM GM862 Cellular Quad Band Module	Like a mobile phone	57.6kbits/s	100$	17-250mA	Serial
WiFi WiFly GSX Serial Module - Roving Networks	100m	2.7 Mbits/s	70$	40-210mA	Serial
ZigBee ZigBee/ZNet2.5 Module	120m	250 kbits/s	38$	35-38mA	Serial
RF RF Link Transmitter - 434MHz	120m	Few kbits/s	4$	3.5mA	Serial
Bluetooth Bluetooth Module - Roving Networks	10m	1.5 Mbits/s	60$	30mA	Serial

Table 1 does not include Bluetooth 4.0 (BLE) since this project ended before BLE became available. Basically, it shows that ZB stands on an average position for each criterion.

Although the final objective was to deploy a multi-hops WSN, the XBs1 modules allow communication between the sensors and a remote server, and to test the emission frequencies. Thus the messages are transmitted (timestamp; ECGval; AXxVal; AXyVal; AXzVal) without any loss by sampling at 500Hz and by transmitting at 57600 bauds. This configuration incurs a significant degree of loss and duplicate messages. In order to preserve a sufficient sampling rate for the treatment of signals (in particular for the ECG which requires a sampling rate around 400Hz), we embed the signal processing and their interpretation on the mobile device (i.e. on the microcontroller). After some optimizations, we lowered the message frequency to 1Hz which is sufficient to send the movement and heart rate. With this frequency, all congestion and message loss was removed.

We created the embedded device (built upon an ATMEGA160AU microcontroller) ourselves, as well as the 14 ZB routers to cover the 3 floors of the museum and the ZB-USB converter on the server. The routers are autonomous and are supplied by a rechargeable 9V battery.

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The ZB network is self-healing: each new ZB module is auto-configured. This functionality was important for two reasons. First, there was no need to link the configuration of a particular node depending on its location. Each deployed node, once powered, broadcasts its IDs so that the closer nodes (i.e. within the transmission range) are aware of its existence, and then propagates, hopping the entire network. Second, this feature preserves an uninterrupted transmission during player movement (roaming), since the "mobile node" is always aware of its surrounding nodes.

4. RESULTS

Over the duration of a game session - which could range from 30mn to 1.5 hours, depending of the player skill - we were able to monitor two players simultaneously. The amount of lost data was under 2%. This good score allowed us to maintain the data stream to the game engine without any significant perturbation. For instance, the heart rate signal never had any rapid significant variations, allowing the loss of a small amount of data without causing disturbance. Although some node power dropped, the WSN compensated for this and the data stream was never significantly interrupted.

5. CONCLUSION

In our project we continuously and simultaneously monitored the heart rate and acceleration of two players moving freely within the space of a building comprising 3 floors, each measuring 2000m². The WSN, built around XBs2 modules, made it possible to cover all rooms of the museum, while respecting the constraints imposed by the institution: discretion of the installation, respect of the building and robustness. The 9V battery supplying some nodes had 5 hours of autonomy, enough for a 1.5 hour gaming session. This hardware architecture presents some excellent features. First, the deployed network is meshed. Hence we can rely on a minimum quality of service (i.e. routing and switching to alternative routes in case of a node breaking down. Second, this technology can be either wall powered or battery powered, avoiding the need to install mains power lines in locations that do not already have them. Third, the shape of a node is very tiny (the size of the XBee module is 24 x 28 x 9 mm) allowing it to be placed in really different places (in the ceiling, stuck to a wall, on furniture, on the floor, etc.)

We are currently working on optimizing the number of routers needed to cover the museum and also on improving the integration on the gaming device (temperature and galvanic skin response ones) so that the issues discussed earlier can be compensated for. One more perspective remains in our ability to use this ZB network to accurately geo-localize people in the museum in order to enhance the game experience by sending contextualised content to the players.

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