M$_i$POS - the Mote Indoor Positioning System *

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Abstract

In the past few years, there have been huge research efforts into ubiquitous and context aware platforms that offer a user a custom level of service based on some known local parameters. The utility of such systems is greatly enhanced if a physical locational area can be determined.

Recently, hybrid devices have been developed combining low power microcontrollers with short range FM radio transceivers. Some location identification work has been carried out with these systems such as the Matrix Pencil approximation technique[8], however most of these all provide information for an ideal square area with no RF obstructions.

Here we present M$_i$POS, a scalable locationing system based on the MICA mote[11] family of devices. The design goal of M$_i$POS is to provide a low-power, scalable, distributed locationing system suited to an indoor (office) environment.

During the presentation of this paper we will highlight solutions in the areas of security, radio and network management and power awareness for a hybrid context aware wearable locationing device.

Key words - *wireless sensor, smart devices, location, adaptive power, clustering, ad-hoc routing*

1 Introduction

Consider a person tracking system which requires minimal or zero configuration, is scalable and uses simple inexpensive hardware for both the tracker and trackee nodes. This is the aim of the M$_i$POS system, which is similar in intent to the Active Badge[10] system, where people wore Infra Red (IR) transmitting badges, tracked by a fixed wired network of receivers.

In our proposed system, every user will carry a M$_i$POS 'badge'. This badge will be a MICA2DOT mote[11] - a 1cm thick circular device with a diameter of 2.5cm - that contains a microcontroller, battery and on board short range FM radio transceiver. Each badge will have a unique ID which can be linked to its carrier. We will refer to these system elements as Badge Node (BNs).

Slightly larger MICA2 motes[11] will be used as static Area Beacon (AB) nodes. Each room or area to be covered will contain an AB, each of which will have a unique ID that can be linked to the specific area it is covering.

It is envisaged that an AB will require little, if any, manual configuration as it will employ some adaptive learning algorithms to determine the characteristics of the local radio space and what, if any, other ABs and BNs are within the range of its coverage.

It is planned to develop and test the M$_i$POS platform in two separate buildings on the Strathclyde University campus. A diagram of the planned coverage area is shown in Figure 1. This will allow us to identify the issues that arise from the dense deployment of both BNs and ABs, evaluate their operation and the performance of the shared radio spectrum in this mix of short hop intra-building and long-hop between building wireless network strategy.

2 Wearable Motes

In the past few years several low power platforms capable of short range communications have evolved. These include devices such as Smart-Its[4], BTNodes[1], and the Berkeley designed MICA Mote[11] platform, which has evolved phenomenally over the last few years. Coupled with TinyOS to handle some of the embedded programming is-

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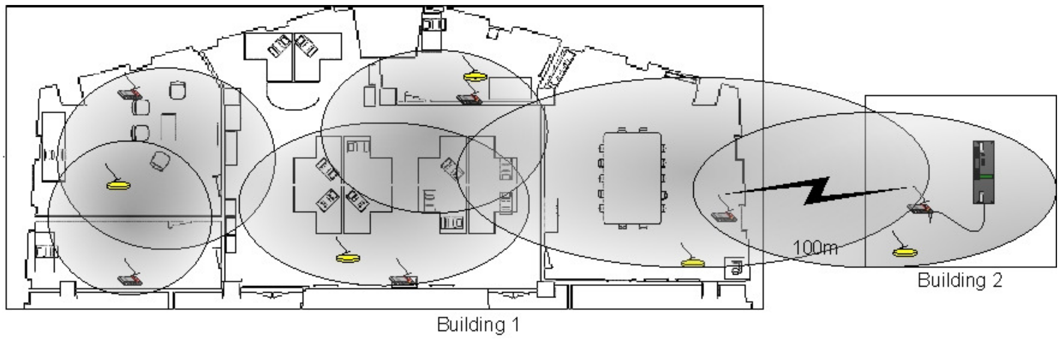

Figure 1: Proposed system layout

sues it is a highly effective development model, and due to its small physical size is ideal for developing ad-hoc sensor network based systems.

Rapid advances in the development of the MICA mote platform have been achieved, and it is predicted that in the next few years the devices will shrink to a fraction of their current size, will consume 90% less power, and will fall in cost to around $1 per node. Mote technology, in the form of Smart Dust[12] has been placed at number one in Fortune Magazine's "Ten Tech Trends To Bet On"[6].

With the potential to deploy huge distributed networks of these devices, it will be of paramount importance to have a scalable locationing system. Furthermore, there are sound technical and economic reasons for such a system to use a common technology for both wearable mobile nodes and tracking/monitoring base stations. In the future, this could be extended with the use of some master nodes with integrated GPS technology to track locations of nodes while the network as a whole is on the move.

3 Challenges and Potential Solutions

Substantial challenges must be addressed when designing a system based on small, low power, embedded devices that incorporate a low power short range communications interface.

- Limited battery life and smart power management
- Sporadic fading and multi-path radio effects
- Ad-Hoc network management and resource allocation/configuration
- Limited processing power and communications bandwidth (38.4Kbps on the MICA2 platform)

We will now consider some of these challenges, and give an overview of proposed solutions which make this project as a whole particularly interesting.

3.1 Adaptive Power Algorithms

As a single shared radio channel is used for mote communication it is only possible for a single node to use the radio space at any one time. It is expected that by using the minimum possible transmit power to send the desired message to the recipient node throughput in densely populated areas will be increased as communications will become more localised. Systems such as GSM use adaptive algorithms to vary the output power of a handset and also the fixed base station. By using as low a transmit power as possible, the network-wide Signal to Interference Ratio (SIR) is increased as nodes only experience interference (and collisions in the shared CSMA radio space) from either physically nearby nodes or, potentially, from higher power transmissions that the ABs use to communicate with distant nodes.

We aim to implement some smart algorithms that will dynamically vary the output power of the MICA motes to localise communications.

3.2 Smart Clustering Configurations

Localizing radio communications naturally leads to a localised network organizational hierarchy, or "clustering" set up. The Multi-Gateway architecture[13] proposes a distributed cluster system with multiple "cluster heads" to alleviate a single network gateway from an overload of sink traffic. A system like this is difficult to implement under TinyOS at present due to the configuration of the radio stack, with each node being allocated static ID parameters. These parameters are determined at compile time, and cannot therefore be altered without changing the contents of the program memory (flash ROM) on the node. While this is a logically clean hierarchical method of organizing network traffic and addressing, it is inflexible and, in the absence of detection methods, if two or more nodes end up with the same node and group ID peculiar effects are likely to be observed.

We propose to investigate dynamic network configuration, which will require a minimum amount of user configuration. These issues have been partially solved in Ethernet networks with the use of Mobile IP and the DHCP protocol. With DHCP, the only fixed ID a host requires is its hardware (MAC) address, and this is guaranteed unique at time of manufacture. A valid IP address is then "leased" from the DHCP server on the local network. With Mobile IP, a node uses two IP addresses - a fixed "home" address and a "care of" address when roaming in a foreign network. Previous research has suggested that IP is not suitable in a dynamic sensor network due to the large overhead of maintaining global routing tables[2]. Recent work however suggests that cut down versions of IP can be used with wireless sensors using the concept of spatial IP addressing[3], where the IP address assigned to a node reflects the location it is currently residing. This scheme lends itself to using subnetting to isolate or group sensors in the same physical area.

In the context of the M$_i$POS project it is desirable to assign a unique ID to each node (so that it can be associated with a location area) but this should not be used for network addressing. Fortunately, all MICA nodes have a six byte Serial ID parameter which is guaranteed unique and could be used for this purpose.

Determining the networking hierarchy dynamically leads to a natural clustering paradigm and also infers the selection or design of some leader election master/slave configuration protocols. From a network management point of view the proposed ideas offer a much more flexible zero configuration solution and removes the need to re-flash units when a change in physical network layout is required.

Once localised clusters have been formed, relative location information can be made available directly from the network topology. By examining both live and historical Received Signal Strength Indication (RSSI) levels of nearby nodes, the absolute location can be refined over time. Other locational techniques suggested by[9] are schemes such as Time Difference On Arrival, however it has been calculated that a TDOA approach in a sensor network which is transmitting 10m in distance will require a network timing accuracy of 3 psec per cm[7].

3.3 Collision Free Radio Space

With the current CSMA based implementation of the TinyOS radio stack, collisions are still possible in the shared radio spectrum. Additionally, with a dense mote deployment there may be a large delay experienced by a node before the radio medium becomes free and data can be transmitted. All nodes are also required to monitor the address field of every incoming packet which results in a substantial power consumption overhead.

A different approach to this irregular access protocol might be to have a more organised, time sliced radio spectrum where nodes can bid for space. Apart from the establishment of the ad-hoc routing tree, the locationing system is likely to be fairly regular, with nodes transmitting information at periodic intervals. This behavior should adapt nicely to a time sliced environment, and with nodes transmitting and receiving at known times, a reduction in node power consumption should be achievable as the radio can be turned off for longer periods of time. This system will require all nodes to be synchronised to an accurate common clock signal.

3.4 Radio Spectrum Considerations

The current generation of mote technology utilise low power radio chipsets which operate in the 433MHz and 916MHz Industrial, Scientific and Medical (ISM) ranges. Although the radio is low power, it is still a large drain of system power, and suffers from multipath and shadowing effects, especially in a crowded indoor environment.

Alternative communications technologies such as Bluetooth and IEEE 802.15.4 have been adapted for short range multi-hop sensor networks, however they do not offer any major advantage over FM technology. Another has been identified - Ultra Wide Band (UWB) radio, an emerging standard for low power high bit-rate communications. This standard has been suggested suitable for sensor networks[5] as it significantly reduces multipath fading effects, and is extremely low power as a carrier frequency does not require to be generated in the transceiver. The technology can deliver very high bandwidths at short distances (125Mbps at 20m) but can also sustain lower bandwidths at longer distances (7 to 8Mbps at 100m). It is this adaption which may prove useful in sensor networks, as it will allow large quantities of data to be moved around in the centre of networks, and still allow a long range link to outlying nodes.

We will investigate the steps necessary to integrate UWB with a mote style system, as using UWB may lead to a much more accurate location system both due to the reduction in path loss and the ability to broadcast more ranging specific messages due to the reduced power consumption.

4 Discussion and Further Work

Preliminary research into the background area of this project area has uncovered some interesting but potentially difficult research challenges. The completion of the practical work should produce some solutions which will benefit both the proposed location system, and other more general projects using low power devices in the ubiquitous domain.

The MICA2 range of motes have both on board sensing capabilities, and the ability to interconnect to a wide variety of devices through general I/O. There is therefore a huge potential to combine other physical information (such as light levels) into the system to provide enhanced information. Most of the proposed research solutions are interlinked, and will combine to provide a more general research platform.

At the workshop we will present details of the M$_i$POS implementation, which will highlight the contribution we have made to the TinyOS radio stack, including routing and security and the contribution the platform can make to context awareness in the ubiquitous computing domain.

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