Institute for System Level Integration

Kelvin® the Kelvin Institute

The University of Strathclyde in Glasgow

M$_i$POS

M$_i$POS
[Mote Indoor Positioning System]

A scalable locationing system

Andrew Jamieson, Stephen Breslin, Paddy Nixon and Duncan Smeed

M$_i$POS Design Goals

- Low-power
- Scalable
- Context-aware
- Wearable
- Locatable (in an indoor environment)
- Secure

Issues

- Security
- Radio and network management
- Power management

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Basic System Components

- Mobile (wearable) Badge Nodes (BNs)
- Static Area Beacon (AB) Nodes

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Badge Nodes

- Worn by user
- Uniquely identifiable
- Microcontroller, battery, and short-range radio in 1cm x 2.5cm disc format
  - Prediction: future devices will shrink to a fraction of their current size, will consume 90% less power, and will fall in cost to around 50p per node.

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Area Beacon Nodes

- Same technology as BN but larger
- Installed in each room or area to be covered
- Self-configuring
  - Adaptive learning algorithms determine characteristics of the local radio space
  - Auto-discovery of other ABs and BNs that are within the range of its coverage.

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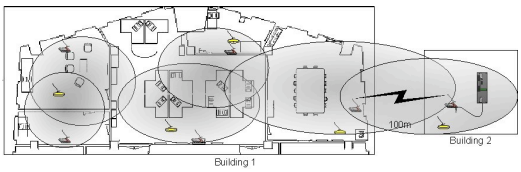
Example deployment



This deployment is designed to:

- expose 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.

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Prototype Node Requirements

- Programmable
- Readily available
  - ideally COTS
- Low cost
- Low power consumption
- Low power wireless communication

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Potential Technologies

- Examples of COTS low-power platforms capable of short-range communications:
  - Smart-Its
  - BTNodes
  - UCB-designed MICA Motes

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Adopted Technology

- MICA2 Motes
  - 4MHz Atmel AtMega 128L microcontroller
  - 128Kbytes program Flash
  - 4Kbytes SRAM
  - 4KBytes configuration EEPROM
  - 10bit ADC
  - ~8mA Active current draw, <15uA sleep
  - 512Kbytes Serial Flash (for sensor data archiving)
  - 38.4Kbits/sec
  - 500(@868/916MHz) - 1000ft(433/315MHz) RF Range (ideal, outdoor)

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Technological Challenges

- 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…
  - 4MHz microcontroller
- …and communications bandwidth
  - 38.4Kbps

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Adaptive Power Algorithms

- Since the radio space is shared only one node can use it at any one time
- By using as low a transmit power as possible, the network-wide Signal Interference Ratio (SIR) is increased:
  - nodes only experience interference (and CSMA collisions) from nearby nodes or 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.

Smart Clustering Configurations

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- Localizing radio communications naturally leads to a localised network organizational hierarchy (clusters).
- Determining the networking hierarchy dynamically also leads to a natural clustering paradigm and hence the adoption of some leader election master/slave configuration protocols.
- 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.

Collision Free Radio Space

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- We will experiment with replacing the CSMA based implementation of the TinyOS radio stack with a time-sliced implementation.
- 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.

Radio Spectrum Considerations

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- The merits of Ultra Wide Band (UWB) radio in sensor networks:
  - significant reduction in multipath fading
  - extremely low power
  - very high bandwidths at short distances (125Mbps at 20m) and lower bandwidths at longer distances (7 to 8Mbps at 100m).
- We will investigate the coupling of UWB with a mote style system, as it may lead to a much more accurate location system due to:
  - the reduction in path loss and
  - the ability to broadcast more ranging specific messages because of the reduced power consumption.

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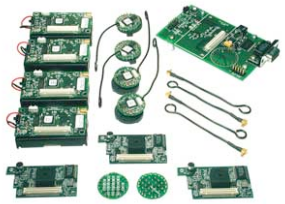
M$_i$POS Platform

- Prototypes built with Crossbow Technology Inc's MICA Motes, and
- TinyOS embedded operating system



Images courtesy of Crossbow Technology Inc.

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M$_i$POS System Components

- Base Station Nodes
  - Master Base Station (MBS)
  - Powered Base Station (PBS)
  - Battery-powered Base Station (BBS)
- Badge Nodes (BN)

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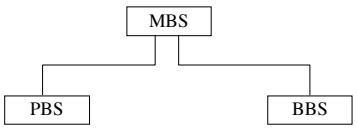
Base Station Nodes



The system will have a hierarchy of Base Station (BS) nodes. This hierarchical structure is extendable, and allows the implementation of different levels of service depending on the resources of the node.

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MBS - Master Base Stations

- Externally powered
- Fixed network connectivity
  - serial link to host
  - ethernet interface
- Radio in promiscuous receive state when idle
- Suitable as synchronisation beacons
  - e.g. sending out regular timing packets

Images courtesy of Crossbow Technology Inc.

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PBS - Powered Base Station

- External power (or large capacity battery)
- Sleeps infrequently - if at all
- Relayer of timing packets

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BBS - Battery-powered Base Station

- Normal standalone MICA2 node
- Powered by two AA batteries
- Sleeps whenever possibl

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Badge Nodes

- Prototypes use MICA2DOT node
- Powered by 3v coin cell battery
- Sleeps whenever possible

Images courtesy of Crossbow Technology Inc.

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TinyOS Communications Protocols

- At the highest level the TinyOS package of routing and transport protocols can be used.
- Currently:
  - **Route** - a simple multi-hop module that forms a very basic layered multi-hop topology.
- Near-term:
  - **MintRoute** - a more complex version of **Route** that is more reliable as it monitors the link cost and quality of up to 16 of its neighbours. Each node tries to find the best route by minimising the total cost while routing a message. Each node broadcasts its cost, where

    NodeCost = ParentCost + LinkCostToParent

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M$_i$POS - Future Plans

- We will be investigating the modifications that will be required to the TinyOS routing algorithms to accommodate reconfiguration, security, and trust issues in the ad-hoc networks that will be created dynamically when BNs move in and out of the rooms/areas covered by ABs.
- Our system will be designed to interoperate with other systems - a prime example being PlaceLab - and provide location aware sensor data.