Energy-Driven Occupant Behaviour Sensing

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September 17, 2020
Motivation

- Occupant Behaviour Sensing
- Energy-Driven Systems
Outline

1 Motivation
   - Occupant Behaviour Sensing
   - Energy-Driven Systems

2 Challenges and Solutions
   - Intermittent Computing
   - Transient Networking
   - Node and Network Architecture

Example: Activity Recognition on WISP
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3 Case Studies
   - Example: Activity Recognition on WISP
Definition

Occupant behaviour study seeks to understand the occupants’ presence and action (OPA) for various purposes, such as comfort management, building energy performance management, health & safety concerns etc.
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- Mechanism: Modelling, heavily data-reliant.
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- Target: Presence and Activity, i.e. opening/closing a window, thermostat operation, movement etc.
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- Mechanism: Modelling, heavily data-reliant.
- Target: Presence and Activity, i.e. opening/closing a window, thermostat operation, movement etc.
- Embedded sensors for quality data.
Examples

- (Kim et. al. 2020)
- Uses a voice recorder.
- Privacy concerns?
Examples

- (Kim et. al. 2020)
- Uses a voice recorder.
- Privacy concerns?

- (Dong et. al. 2011)
- Heterogeneous network of sensors.
- Cost of Maintenance?
Energy-Driven Systems

Definition

Self-powered, i.e. energy-harvesting, systems where there is explicit consideration for the systems’ power supply/demand characteristics early in the design process.
Energy-Driven Systems

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- Infinite life-time means zero maintenance, e.g. battery replacement and disposal.
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- Simplified devices with smaller BOM, but significantly harder design process.
- Extra dimension for design trade offs.
- Instead of adding a harvester to prolong battery life, design around the harvester such that application requirements can be met. Maybe that battery is not required?
Example

A battery-less cycle computer. (Wong et. al. 2018)

- 2.4 GHz wireless link.
- No batteries required.
- Shape of pulse used to determine angular velocity.
Indoor Energy Sources

(Ernesto et. al. 2019)
Indoor Energy Sources

(Edward et al. 2019)

(Pavegen.com)
Indoor Energy Sources

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Indoor Energy Sources

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Indoor Energy Sources

(Ernesto et. al. 2019)

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(solar)
Problem

Power supply is intermittent. Device power cycles during computation in an unpredictable manner resulting in loss of data and/or computation progress.

(Solution - quite mature, focus is on efficiency)

Sustain computation through intermittent power cycles using checkpoints or other schemes with the goal of maximizing forward progress in the compute task. (Balsamo et. al. 2015)
Intermittent Computing

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(Balsamo et. al. 2015)
Transient Networking

**Problem**

1. Nodes go offline intermittently. Clocks go out of sync.
2. Energy availability vary among nodes in the network.
## Transient Networking

### Problem

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### Solutions/Proposals

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<tr>
<td>1</td>
<td>Simultaneous wireless information and power transfer.</td>
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<td>Wake-up Radios.</td>
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<td>3</td>
<td>Energy-aware networking/routing protocol.</td>
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Transient Networking

Problem

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Solutions/Proposals

1. Simultaneous wireless information and power transfer.
2. Wake-up Radios.

Complications/Motivation: IoT

Internet Protocol on Energy-Driven nodes? Security?
Node and Network Architecture

(sensor node w/ solar cell)

Environment Sensor

Node and Network Architecture

(Mesh, Cluster Tree, STAR)

IETF IoT Protocol Stack
- Application Layer: IETF COAP
- Transport Layer: UDP
- Network Layer: IPv6, IETF RPL
- Adoption Layer: IETF 6LoWPAN
- MAC Layer: IEEE 802.15.4 MAC
- Physical Layer: IEEE 802.15.4 PHY

TCP/IP Protocol Stack
- Application Layer: HTTP, FTP, DNS, SSH, SMTP, NTP, ...
- Transport Layer: TCP, UDP
- Network Layer: IPv4, IPv6
- MAC Layer: Network Access

(icpdas-usa.com)
Example Application
Activity recognition from WISP accelerometer measurements.

- Sensor data and image from (Wickramasinghe et al. 2017)
- WISP is a battery-less RF powered tag.
- Type of activity can be discerned easily from the sparse accelerometer data.

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<tr>
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<th>Test</th>
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<tr>
<td>Sit on Bed Precision</td>
<td>0.99</td>
<td>0.97</td>
</tr>
<tr>
<td>Sit on Bed Recall</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Sit on Chair Precision</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>Sit on Chair Recall</td>
<td>0.95</td>
<td>0.92</td>
</tr>
<tr>
<td>Lying Precision</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Lying Recall</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Ambulating Precision</td>
<td>0.98</td>
<td>1.0</td>
</tr>
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