Teknologiasta liiketoimintaa

M3 Based Knowledge Sharing Protocol Applied to Bluetooth LE Sensors and Actuators

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Goal and Method of the Research

- **Goal:** to demonstrate that low capacity devices can be part of semantic interoperability, without undue adverse effects on requirements for
  - Power supply
  - Processing power
  - Memory size
  - Communication capability
  - Cost

- **Method:**
  - Application of Knowledge Sharing Protocol (KSP) to M3 architecture, consisting of a local Semantic Information Broker (SIB) and Knowledge Processors (KP) that operate as sensors or actuators, utilizing Bluetooth Low Energy as a means for data transport.
  - Implementation in real HW and SW (some KPs in simulation only)
  - Appropriate measurements for figures such as required memory and power consumption

Key Technologies

Knowledge Sharing Protocol (KSP)

- A novel knowledge sharing protocol (KSP) for semantic technology empowered ubiquitous computing systems
- Designed to be used with M3 architecture
- Utilizes a compact, binary format that is designed to be suitable also for resource restricted devices and networks
- Can be used on top of various data transport layers
- **Refer to Jussi Kiljander's separate presentation about KSP**

<table>
<tr><td colspan="5">M3 application logic</td></tr>
<tr><td colspan="5">KSP</td></tr>
<tr><td>TLS</td><td>DTLS</td><td>CoAP</td><td>RFCOMM</td><td rowspan="4">others</td></tr>
<tr><td colspan="2">TCP</td><td colspan="2">UDP</td><td rowspan="2">L2CAP</td></tr>
<tr><td colspan="2">IPv4/IPv6</td><td colspan="2">6LoWPAN</td></tr>
<tr><td colspan="2">Ethernet/
WiFi</td><td colspan="2">IEEE
802.15.4</td><td>IEEE
802.15.1</td></tr>
</table>

Bluetooth Low Energy

- Marketed as *Bluetooth Smart*
- Included to Bluetooth Specification 4.0
- Enables a new class of devices with very low power consumption, low cost and long operation times even from a small 3V coin cell battery
- Profiles have been defined for various applications such as health care, sports and fitness.
- Texas Instruments CC2540 ”keyfob” development kit is used as a platform: 8051 microcontroller with 128 kB flash and 8 kB RAM memory.

Bluetooth® SMART

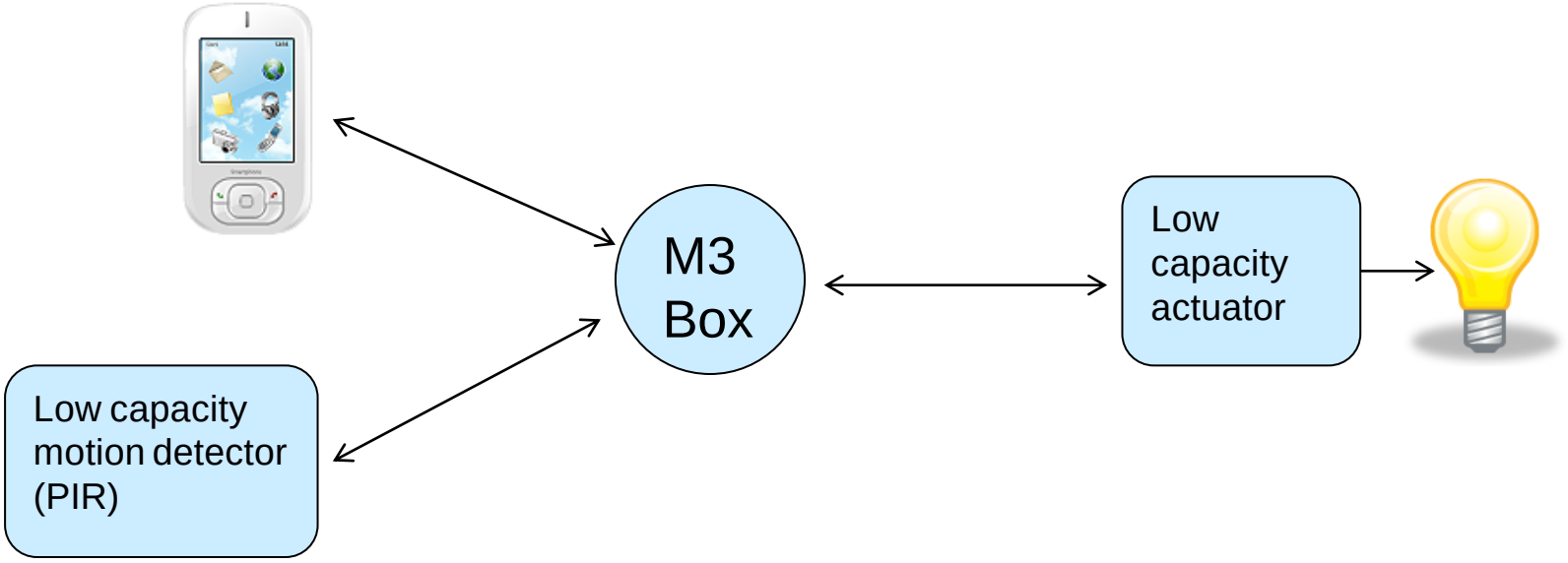
M3Box

- A SIB platform by VTT
- In this case, M3Box runs a SIB implementation that can communicate using KSP compatible messages
- Based mainly on Seco Qseven Quadmo747-E660 single board computer with Linux operating system

Demonstration Scenario

Incremental Applications, step 1/3

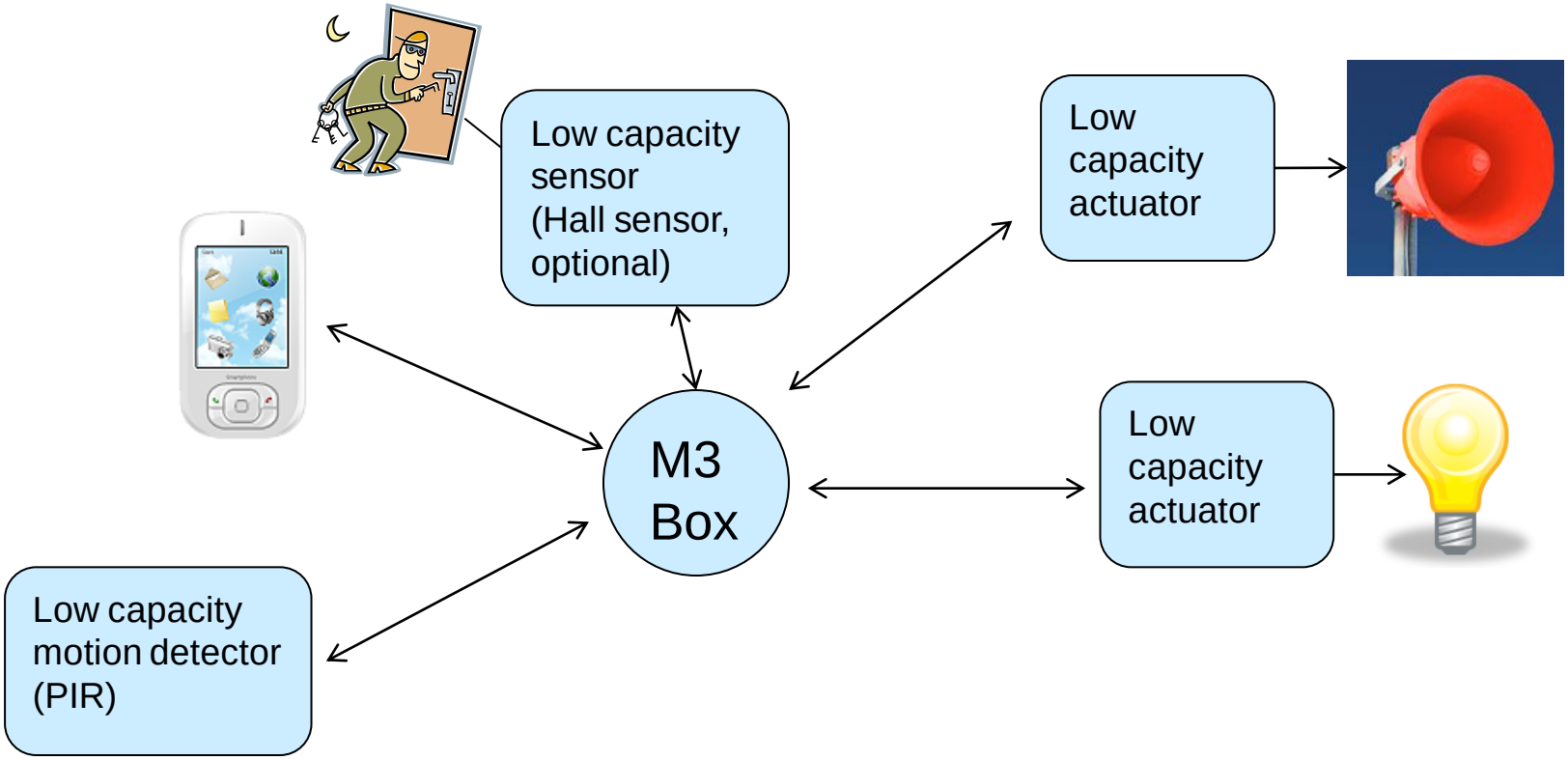
- To demonstrate the versatility of semantic technologies in smart spaces
- **Phase 1)** A basic application exists and consists of M3Box and low capacity sensors/actuators
  - Automatic lighting control based on user presence/location
  - User presence information based on mobile phone connection (e.g. BT LE)
  - User location based on motion sensor
  - Based on this data, the actuator will switch the room light on/off



Incremental Applications, step 2/3

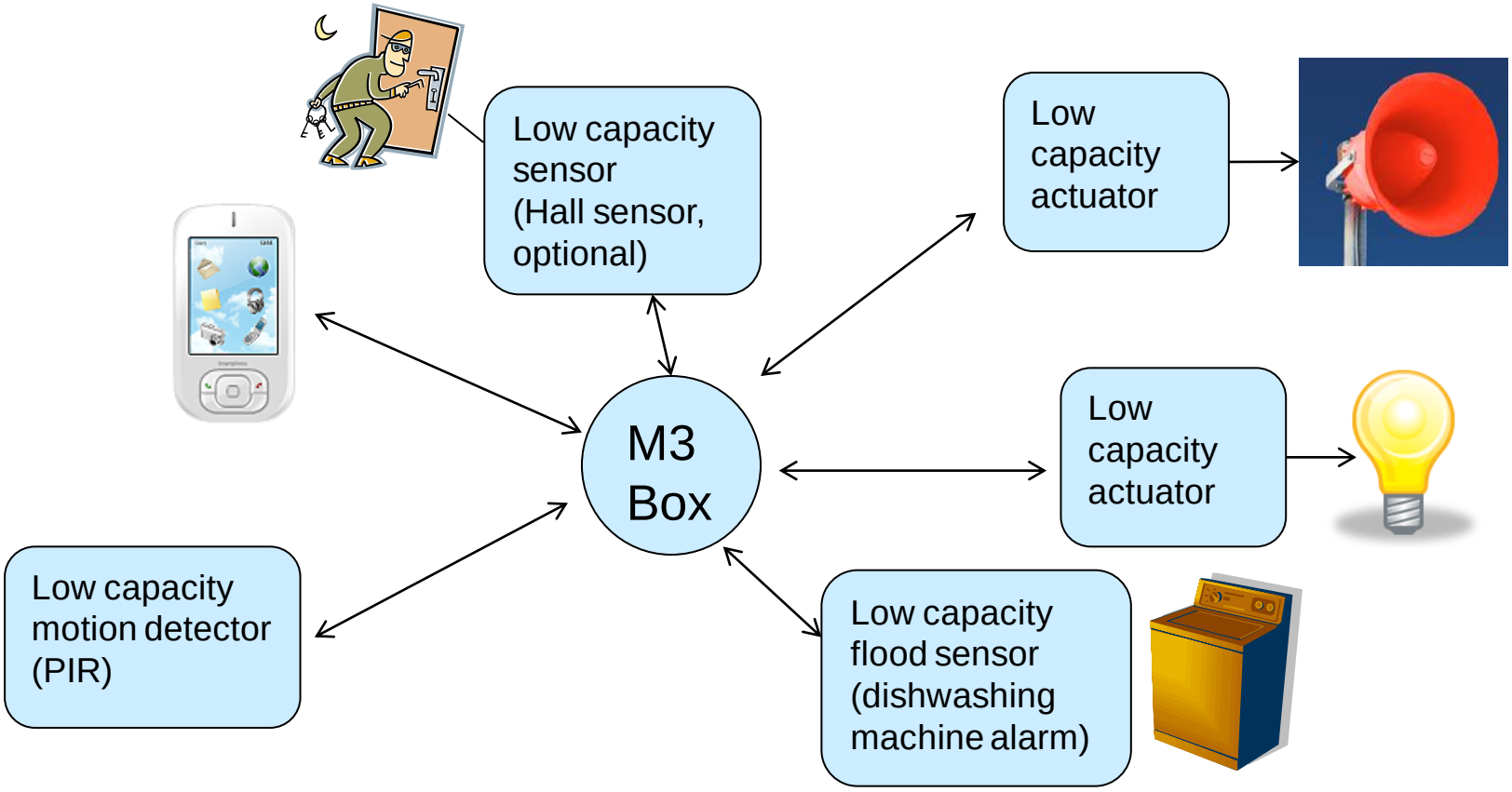
Phase 2) A siren and a door sensor (optional) are added to the system. The user wants to utilize also the existing motion sensor to implement an alarm system.

- Based on semantic technologies, this is basically possible. If motion is detected when no user is logged in, an alarm is triggered.

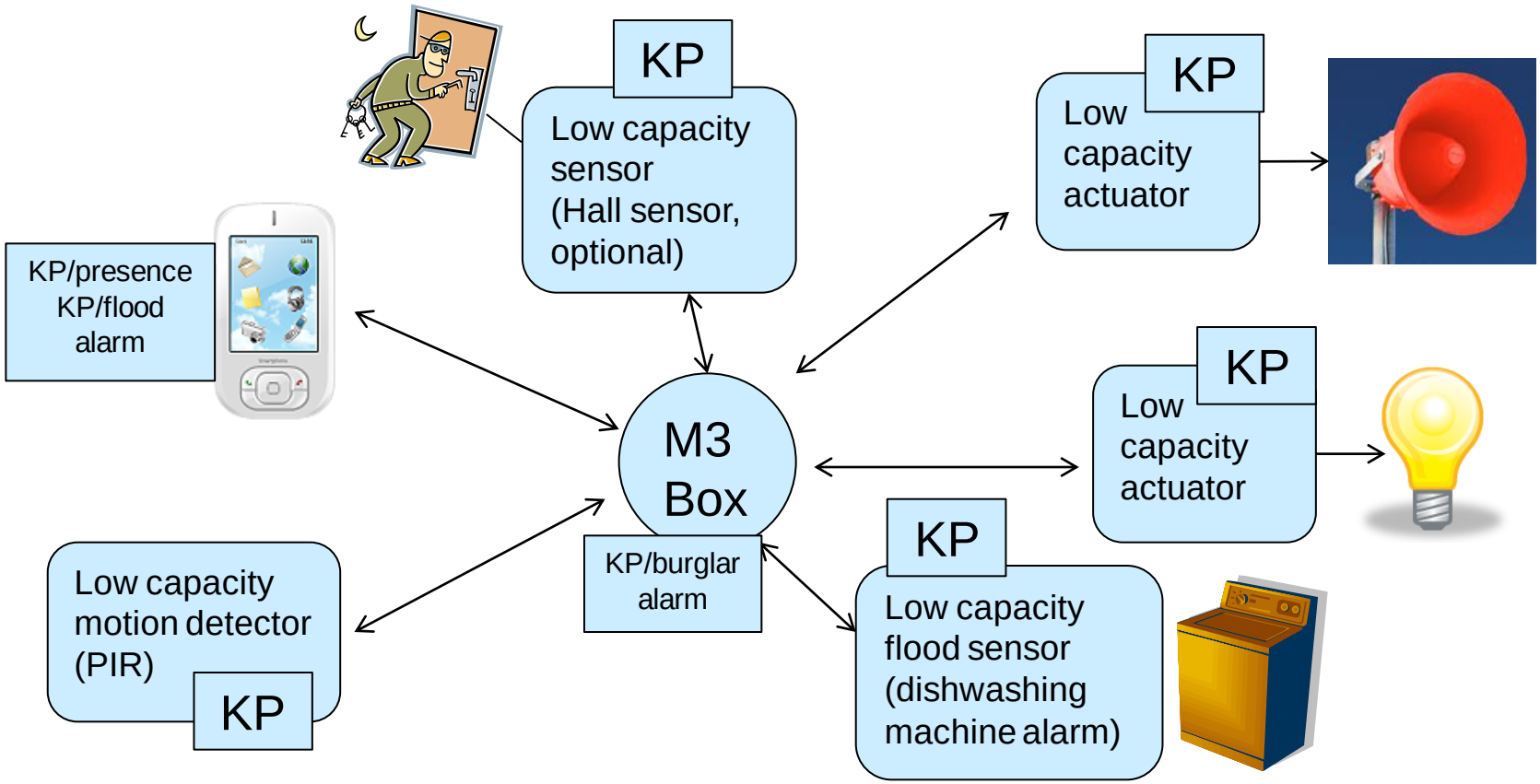


Incremental Applications, step 3/3

Phase 3) A flood sensor is added to the system. The user wants to monitor leaks under dishwashing machine to prevent damage caused by water. The siren that was purchased for burglar alarm application is re-used. In addition, smartphone application shows the reason for alarm.



Knowledge Processors (KP)



Implementation and Performance

Implementation

- M3Box HW and encapsulation have been implemented, SW development in progress
- SIB code with KSP support exists
- KSP has been implemented to the Bluetooth Low Energy motion sensor
  - A novel *KSP Bluetooth Low Energy Profile* has been implemented
- Work in progress with KSP enabled lighting control node (Bluetooth Low Energy)
- Some of the KPs will be simulated instead of physical implementation

Effect on Memory Consumption

Bluetooth Low Energy PIR sensor without KSP:

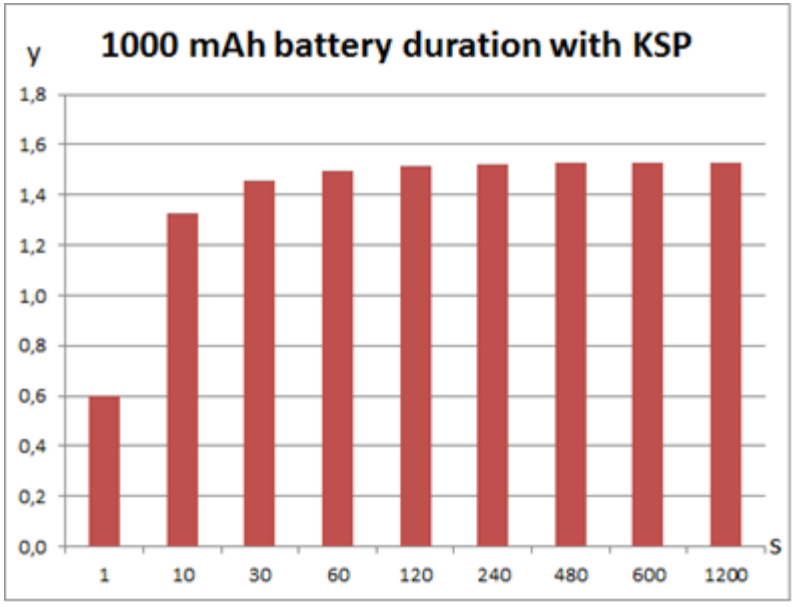
- Flash memory consumption 113 423 bytes
- RAM memory consumption 6289 bytes

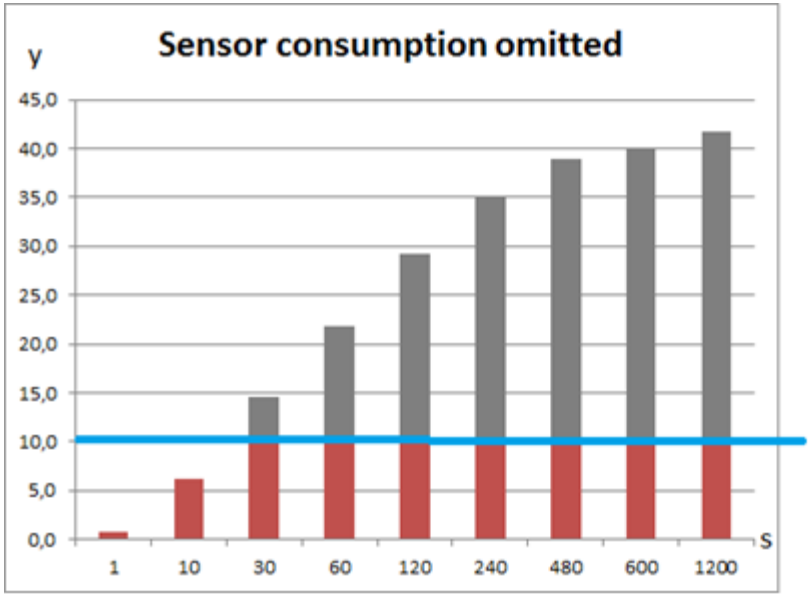
Bluetooth Low Energy PIR sensor with KSP:

- Flash memory consumption 125 880 bytes **(+11%)**
- RAM memory consumption 6483 bytes **(+3%)**
  - Remark: may be increased up to ~5% in future enhanced version with larger writable characteristic for received KSP messages in the Bluetooth profile.

Power Consumption

- The figures show theoretical duration of the battery pack used (3 x 1,5V AAA batteries in series) as a function of sensor event frequency.
- Sensor event: “Motion detected” is reported to the BT master, followed later by “Motion not detected”.
- NON type KSP messaging: SIB does not need to acknowledge in KSP level.

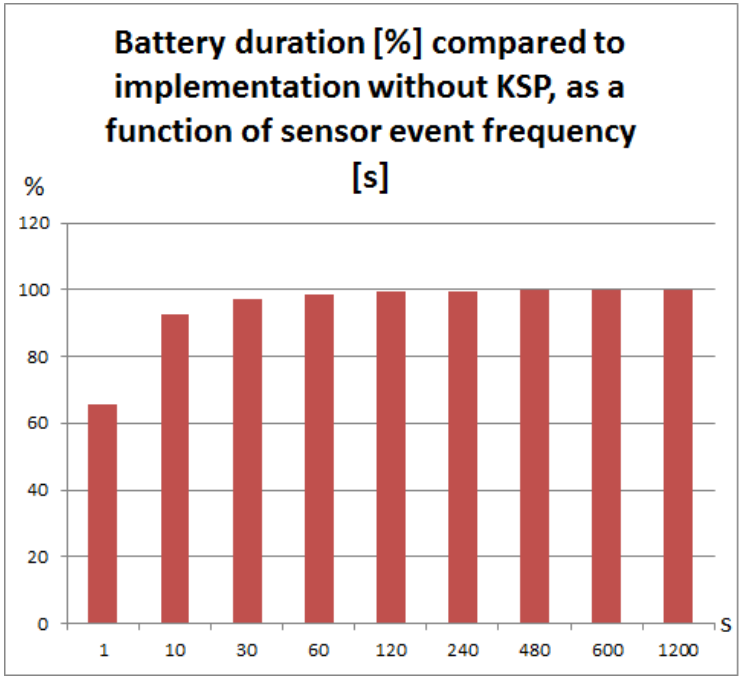


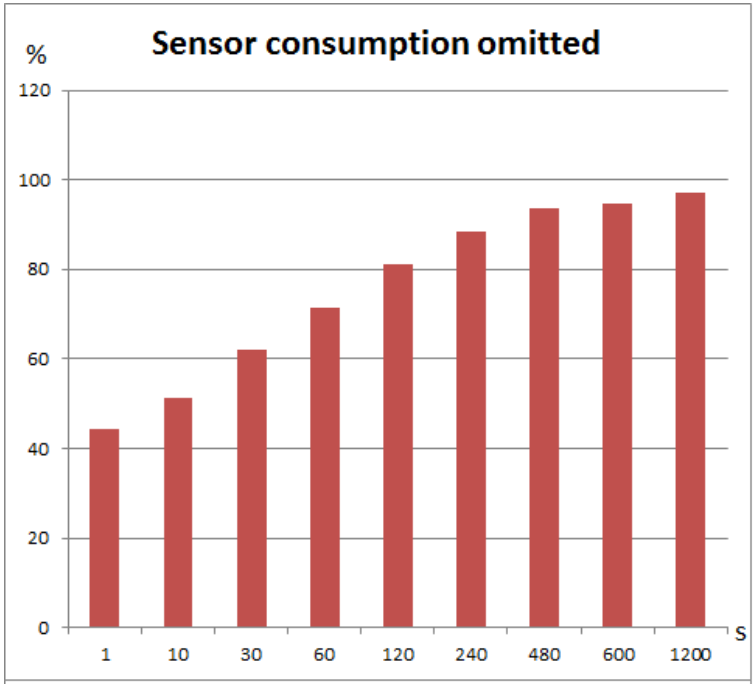


Realistic battery life not much longer due to battery self-discharge

Battery duration compared to implementation without KSP

- The figures show the percentage of battery duration compared to implementation without KSP, as a function of sensor event frequency.
- KSP data format increases power consumption, since a “motion detected” or “motion not detected” needs to be sent in five different BT LE messages (instead of only one in case of non-KSP implementation), each containing 20 bytes of data payload.





Conclusion

- The implemented PIR sensor demonstrates that KSP is feasible on top of
  Bluetooth Low Energy transport and a low capacity microcontroller.
- Increase with memory consumption was relatively modest and did not require switching to a chip version with higher memory resources; no additional cost in this case.
- There is a notable effect on power consumption and therefore, battery duration, but its significance depends on:
  - how data intensive the application is
  - Does the radio communication dominate power consumption, or something else such as sensing
- In a practical motion sensing scenario, the KSP's effect on power consumption or battery duration is negligible.