Efficient energy use of local and remote data processing.

Team members:

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Introduction:

Broadband Internet is become more widely available, the cost of connecting is decreasing, more devices are being created with Wi-Fi capabilities and sensors built into them, technology costs are going down, and smartphone penetration is sky-rocketing. These things are creating a "perfect storm" for the IoT.

The Internet of things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to connect and continuously generate data and transmit it over the Internet.

This trend has opened new possibilities for wireless networks. One of them is the creation of Wireless Sensor Networks, this kind of network works with a lot of sensor nodes measuring several physical phenomena, such as pollution, wind speed, noise, etc., and then sends the data to a central location in order to process it and be able to obtain information from it. The creation of such a network involves the use of autonomous devices that must work most of the time without any kind of wire, so all transmissions must be wireless, and the device must function with a battery.

Problem formulation:

We need sensor nodes to be able to keep sending information as long as possible. This is the reason behind the development of different low-power transmission. However, the full potentials of new wireless technology in the case of power saving has not been reached.

Lots of work has gone into solving this problem and several approaches have been suggested and found to be successful. The different approaches can be classiffed into three groups [3]:

Duty cycling: The idea here is that there is no need for all nodes to have their radio on all the time. Nodes will turn their radio off when there is no network activity and wake up

depending on the chosen schema. The power consumption of the radio is greatly reduced if the nodes use this approach, though in sensors where the measurement need a lot of power it will not work as well.

Mobility-based: It tries to handle the power consumption when the node is in movement following predictable or totally random patterns.

Data driven: This approach tackles the issue of when to take a measurement and how to send less data to the network, also reducing the time the radio and the sensors are on.

For this project we will focus in the third group.

To evaluate power efficiency of local and remote data processing, we were planning to implement gesture recognition based on accelerometer data, but due the short time we will let this task for future research and for now we implemented BLAS (Basic Linear Algebra Subroutines).

BLAS-1

$$O(n)\text{data}$$
$$O(n)\text{ operations}$$
$$c = a * b^T$$
$$(a_1, \dots, a_n) * \begin{pmatrix} b_1 \\ \vdots \\ bn \end{pmatrix}$$

BLAS-2

$$O(n^2)\text{data}$$

$$O(n^2)\text{operations}$$

Matrix-by-vector product

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} * (b_1, \dots, b_n)$$

BLAS-3

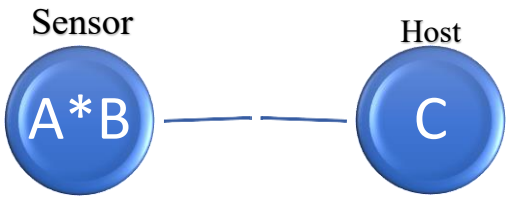
$$O(n^2)\text{data}$$

$$O(n^3)\text{ operations}$$
Matrix-by-matrix product

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} * \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{pmatrix}$$

We compute the code using C99 and we used the functions arm_mat_add_q31 and arm_mat_mult_q31 from the library arm_math.h. We take the algorithm then, in case of local data processing, the recognition takes a place on smart sensor side and only small alarm message sent wirelessly to host. For remote processing, all recognition happens on host side and all raw data sent over wireless channel. At the end of project, power waste for local and remote processing will be compared.

Local Data Processing



Remote Data Processing

Data:

We used real-time data coming from spread hardware platforms nrf52 + MPU 6050 and cc2560 sensor tag based on new Bluetooth Low Energy wireless standard. It has sensors for: temperature, digital microphone, light, accelerometer, pressure, humidity, magnetometer.

We used matrices size 10x10 and vectors 10 elements and calculated/send data every 200 milli seconds.

Related work:

Lots of work has gone into solving this problem but not so much for the special case of Bluetooth sensors. Only, Bluetooth Special Interest Group came up with standard for basic wireless interaction. The list of standards is: (https://www.bluetooth.com/specifications/gatt/services).

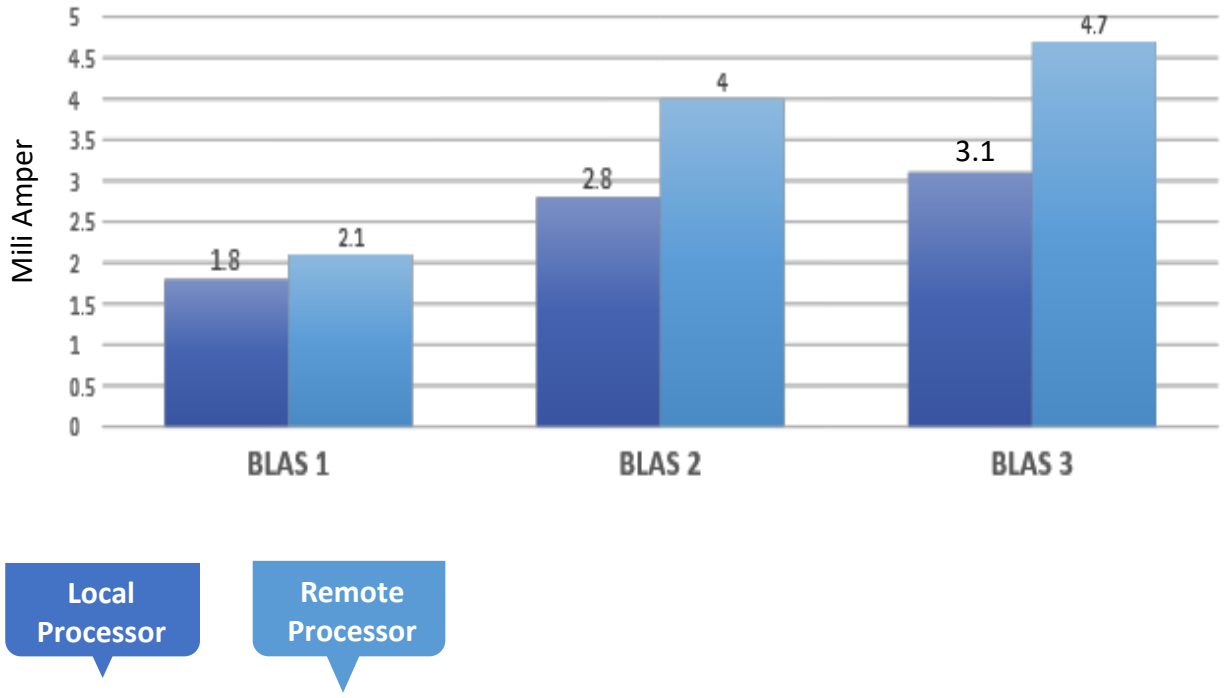
Scope:

Compare of energy usage of local and remote data processing. This analysis may be useful for select the most optimal way to process data according to the characteristics of the task and do it in an efficient way.

Evaluation:

To evaluate power waste of data processing, we used a multimeter and power profiler kit and software provided by Nordic semiconductor to measure the power consumption of our three different experiments. (https://www.nordicsemi.com/eng/Products/Power-Profiler-Kit).

Results:



Conclusions

We can conclude that it is better to process data in a local way. For our experiments we find that by processing data in local way we can save between 1 to 1.5 years of battery life for a Lithium battery CR2032 that is the battery that our sensor uses (We determinate this using the battery life calculation from: https://www.maximintegrated.com/en/design/tools/calculators/product-design/battery.cfm).The save of energy is because instead of sending a big amount of data over the channel, it is send just a small piece of data. Most power usage goes up due to data transfer, not processing.

As future work, we intend to analyze more complex models as the original idea for the project and compare the power consumption of the both implementations.

Reference:

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