Demo Abstract: Crowd analysis with infrared sensor arrays on the smart city edge

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***Abstract*—Smart cities infrastructure is currently highly centralised, relying on data centers or cloud technology to tackle diverse application requirements. To reduce the transmission latency and the data volume towards the cloud infrastructure, a next step to be explored includes the introduction of edge computing into such an environment, bringing the computational power closer to the Internet of Things devices. In this paper we present a hands-on demo smart city edge computing application. It shows the advantages of edge computing by analyzing incoming sensor data on people movement via edge computing, which results in faster processing, lower latency, and lower bandwidth consumption.**

***Index Terms*—Smart Cities, Edge Computing, Internet of Things, Infrared sensors**

I. Introduction

The Smart cities domain covers a broad range of Internet of Things (IoT) applications which aim to improve the city and the life of its citizens. To support this diversity, multiple wireless technologies must be available for the diverse sensors and actuators deployed in a such smart city. Gateways are used to house multiple wireless technologies and to provide the needed connectivity. Moreover, with the rise of edge computing, more functionality is added to such gateways by adding computing capabilities using the distributed computer paradigm, which operates on the *edge* of the cloud. Instead of directly sending the data to the cloud-computing infrastructure to be processed, the data is partially processed on edge nodes to promptly take the correct actions for nearby devices with a lower latency and a lower upstream bandwidth usage. The processing power of edge nodes is limited and distributed, as opposed to cloud-based computing services which are used for storage and a more detailed analysis, combining data from multiple physical locations. The demonstration described below shows how smart cities can take advantage of edge computing to solve problems in terms of latency, data transfer size and costs. We build a setup which uses multiple infrared sensors at a given location to analyze the crowd. The sensors transmit continuous data streams to the gateway where the data is processed to rapidly produce an indication of the crowd size. Because the raw sensor data is already processed at the gateway, we are able to reduce the data transmitted, and thereby reduce the costs to send the data the a cloud infrastructure for a more detailed analysis.

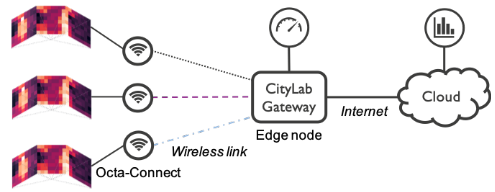

Fig. 1. Experimental setup of the demo.

II. CityLab smart city testbed

The CityLab testbed is a smart city testbed for experimentation in the city of Antwerp (part of the City of Things programme) [1]. It is a collection of multi-technology wireless gateways deployed in the city, aimed at IoT applications. The gateways are controlled via Emulab[1], a central management system, and researchers can access and allocate the gateways via jFED for experiments [2]. A CityLab gateway can be used as an edge node with limited processing power to enable low latency interaction between sensors and actuators and to limit the data traffic towards the cloud computing infrastructure, and most importantly to reduce latency.

The CityLab gateways are composed of three units: an indoor unit, an active outdoor unit and a passive outdoor unit. The active outdoor unit can be accessed by researchers via jFED. It contains an x86 PCEngines APU embedded device which is connected to a set of radios used for a wide variety of wireless technologies, such as WiFi, Bluetooth and Zigbee. Each radio is connected to a dedicated antenna enclosed in the passive outdoor unit. The active outdoor unit is connected to the indoor unit to connect to a secured network, over academic fiber. The indoor unit allows to reboot the active outdoor and, if needed, remote recovery from almost any error situation.

III. Demo

In this demo we will show the advantages of edge computing by introducing a wireless multi-sensor network with high computing power and low latency requirements, as shown in figure 1. We created an experimental setup to estimate the size of the crowd using an array of infrared sensors. Each sensor array contains three infrared sensor grids which communicate with the gateway, the edge node, via one of the available wireless technologies. The gateway processes this data and

[1]https://www.emulab.net

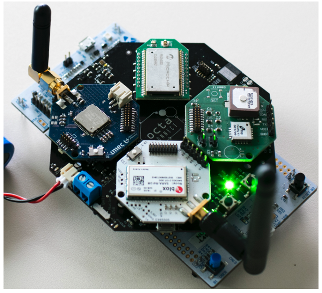

Fig. 2. Octa-Connect platform with multiple shields.

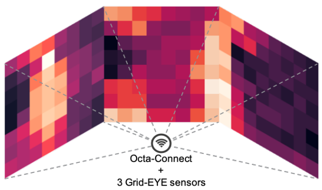

Fig. 3. Octa-Connect with three Grid-EYE sensors connected with a 180° field of view.

produces an estimation of the crowd size with a low latency. The processed and reduced data is uploaded to the cloud for post-processing, generating higher accuracy results.

The infrared sensor array consists of three Grid-EYE infrared array sensors [3] integrated on the Octa-Connect platform, a fast-prototyping platform for IoT applications shown in figure 2. The Grid-EYE infrared sensor is an eight by eight thermopile array sensor which is able to detect a surface temperature between $-20\,°\mathrm{C}$ and $100\,°\mathrm{C}$ with a maximum frequency of 10 Hz. The sensor detects temperatures with a 60° viewing angle and a maximum distance of $7\,\mathrm{m}$. By using an infrared sensor we maintain the privacy of the people passing, allowing the system to be used in low light conditions and limiting the costs. By aiming the sensors at different angles at the target location, as shown in figure 3, we can already calculate an estimation of the crowd at the gateway. We can correlate the data with other sensors for movement and flow analysis, taking into account the low latency of analysing simultaneous data from people walking by. A more detailed analysis can then be done at the cloud, e.g., counting people more exactly or determining their exact walking speed.

For our demo setup we bring a gateway of the CityLab testbed and multiple Octa-Connect platforms which collect the sensor data from the multiple Grid-EYE sensors and transit this sensor data via a wireless interface to the gateway. The advantage of the Octa-Connect platform is that multiple shields can be plugged easily. A shield is a small platform which houses a sensor or a wireless interface. For this demo we use multiple shields with a wireless interface and a shield to connect the Grid-EYE sensors the platform. Each sensor sends an array of 64 temperature values to the Octa-Connect platform via the $\mathrm{I^2C}$ bus. For three Grid-EYE sensors a total of $31.2\,\mathrm{kb/s}$ data is generated and sent to the gateway.

We use Wi-Fi, Bluetooth and DASH-7, a low power long

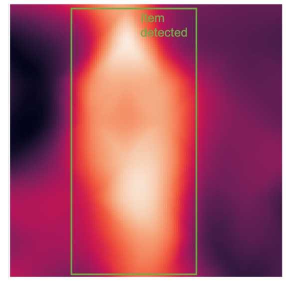

Fig. 4. Image recognition from the data of one grid-EYE sensor.

range sub-GHZ wireless technology, to connect the Octa-Connect platforms to the gateway. The wireless connections enable the mobility of sensors across the location, as long they are in range of the gateway. The gateway gathers all sensor data to estimate the current size of the crowd. For detailed analysis of the sensor data, we use our cloud computing infrastructure, located at the University of Antwerp. Figure 4 shows results of the image of one grid-EYE sensor with image recognition applied to it, as performed on powerful compute infrastructure. The latency and cost of uploading depends on the location and the up-link specifications of the gateway. Low bandwidth backhaul (such as LoRa or Sigfox) and the ability of a continuous connectivity have an impact on the amount of data sent to cloud infrastructure.

For the image recognition we use a trained deep neural network to detect humans shapes. We previously trained the network by labeling the infra-red images by marking people as seen in figure 4 via boxes. During the training period, in order to label the images, we used a camera as reference image aimed at the same location and synchronized the image of the camera with the image of the infra-red sensor.

IV. Conclusion

In this demo we proposed an application which represents a typical application in a smart city where bandwidth and latency are important. The crowd monitoring application uses multiple wireless technologies to send sensor data to a gateway. The gateway acts as an edge node, processing the data from the infrared sensors to produce a first estimation of the size and direction of a crowd. Aggregated data is then sent to the cloud for post-processing, to perform a detailed analysis about the crowd size and movement. By using the gateway as an edge node, we reduce the data transmission volumes and we enable correlation of sensor data.

References

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