Long-Term Environmental Monitoring WSNs In to the Internet of Things

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Abstract: The confluence of distributed cloud networking and the IoT will enable a new range of services in “smart” environments (e.g., smart cities, smart grids, smart transportation systems). Wireless sensors are planned to be a fundamental part in this new paradigm and therefore their efficient integration is critical. On one hand, the IoT-Cloud augments the computing resources of sensors and extends their battery life. On the other hand, the data gathered by different sensing platforms can be shared on a bigger scale, enabling a more efficient exploitation of the physical infrastructure. In WSNs were assumed to be isolated networks that merely collect specific data to be gathered at a central server. However, thanks to the recent advances in network programmability and virtualization, wireless sensors can be integrated into IoT-Cloud networks as distributed sensing and computing resources. In this paper, we formulate this problem as a minimum cost flow problem using only linear constraints. The objective is to the find the optimal placement of virtual functions over the IoT- Cloud that meets user requests, satisfies network resource capacities, and minimizes overall network cost. We solve this problem for an illustrative set of smart city services, where users interact with the city using their smart devices.

Keywords: IoT, WSN, Cloud, Cloud Network, Smart Cities.

1. Introduction

The Internet of Things (IoT) connects many heterogeneous devices, such as wireless sensors, RFID devices, smart phones, wearable’s and connected vehicles, which produce and/or consume information in real-time. When connecting the IoT to the Cloud, in- formation collected from multiple locations can be processed and analyzed to produce meaningful information, which can be accessed remotely [Ala13]. At the same time, the intrinsic limitations of lightweight mobile devices (e.g., battery life, processing power, storage capacity) can be alleviated by taking advantage of the extensive resources in the Cloud using offloading techniques [Kum10]. The resulting IoT-Cloud paradigm enables the network designers to implement a new breed of services and applications (e.g., health system monitoring, traffic control, energy management, vehicular networking), which are expected to define the essence of next generation smart environments (e.g., smart cities, smart homes, smart grids [Bot14]).

With the increasing number of services and connected devices, IoT traffic is expected to grow dramatically in the coming years [Wen14]. In order to satisfy the QoS requirements of end users and increase the network efficiency, cloud networks are becoming increasingly distributed (i.e., composed of a large number of dispersed cloud nodes). This has motivated the placement of low complexity cloud nodes in close proximity to the device layer, such as cloudlets [Sat09] or micro-clouds [Shi13]. In this context, and with the particularities of the IoT in mind, in [Bon12] the authors propose to expand the Cloud paradigm up to the device layer, creating the so-called Fog, making the analogy with a cloud close to the ground. In fog networks, the end-layer can handle part of the computational tasks [Zhu15]. As a result, the latency and resource utilization of the network resources can be improved compared to traditional cloud computing [Aaz14].

2. IoT-Cloud in Smart Cities

Smart cities are a clear example of the huge potential of the IoT. These connect many wired and wireless devices to provide services that enhance the wellbeing of people (Figure 2.1). Smart cities aim to improve many city services, such as the system health monitoring, traffic mobility, waste management, energy management and healthcare. The general structure of smart cities includes a device layer, a transmission layer and an application layer (Figure 2.2).

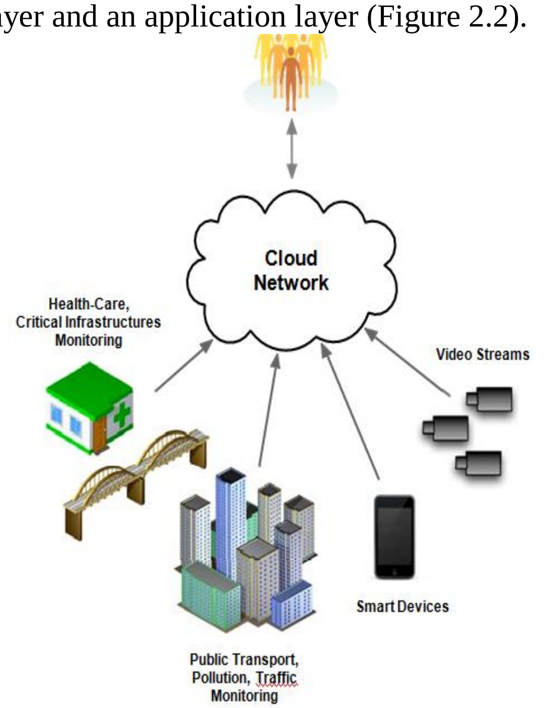

Figure 2.1 Smart city architecture

The device layer provides raw data from sensing devices and also requests processed information. In general, there are nodes that only provide data (e.g., distributed sensors, cameras, RFID, GPS), nodes that only request information (e.g., actuators, public screens), and nodes that may both provide and request information (e.g., smart devices). The network layer transports both the raw data to the cloud servers, and the processed data to the end devices. This layer combines wired and wireless links, with different technologies. Finally, the application layer processes and analyzes raw data to generate the information requested by the device layer.

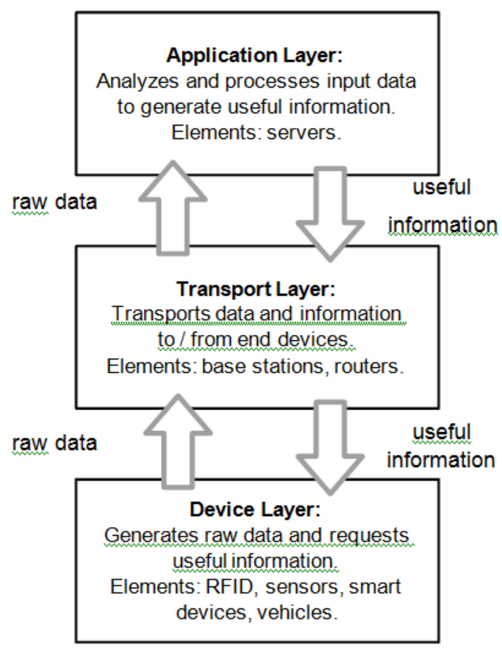

Figure 2.2 Smart cities layers

Traditionally, a centralized cloud scheme in smart cities was considered to be the most efficient solution, since the consolidation of processing resources in a single location reduces the operational cost of the network. However, recent works indicate that the network performance can be improved by doing more processing close to the end users [Sat15], [Ha13]. In this context, [Sat09] and [Shi13] are initiatives to place distributed near-user cloud nodes. Thanks to the recent advances on mobile computing [Lei13] and virtualization [Nas14], the device layer can also be integrated into the cloud network. Then, smart cities can be modeled as converged IoT-Cloud networks in order to efficiently manage their resources, enhance their QoS, and reduce their energy consumption [Bon12].

In this scenario, sensors, smart phones, connected vehicles, and the rest of mobile devices, are not simple endpoints, but storing, sensing and computing resources. With this level of abstraction, they can be orchestrated together, and also interact with the cloud resources. Some of the advantages of the IoT-Cloud paradigm in smart cities are:

- Low latency: the processing can be placed at the edge of the network in order to support latency sensitive applications.
- Geographical distribution: It allows widely distributed cloud systems, since the device layer is an active part of the Cloud.
- Large scale sensor networks: The interoperability of WSNs from different providers creates larger virtualized sensing platforms.
- Location aware and mobility support: The current location of users can be used to provide service mobility.

3. Simulation Results

In this section, we solve the IoT-Cloud SDP to minimize the overall network consumption of three illustrative smart city services via the linear programming solver Xpress-MP.

In particular, we analyze: i) the virtual fog service network solution (vFSN), which allows tasks to be processed anywhere in the network, ii) a distributed cloud approach, which places tasks in any cloud node, and iii) a fully distributed approach, which allocates all the processing at the devices level.

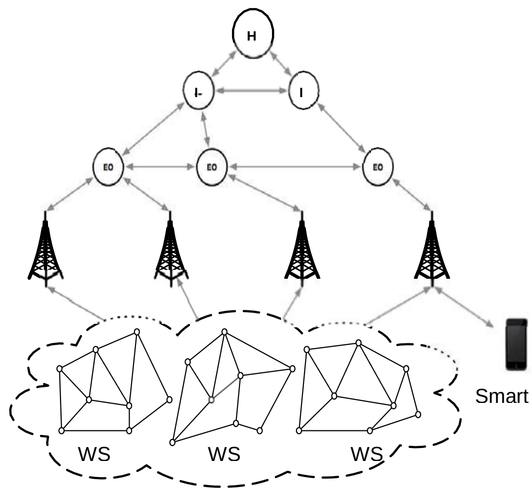

Figure 3.1 Structure of the smart city

3.1 Smart City Scenario

We consider the smart city network in Figure 3.1 that includes wireless sensors, smart devices (e.g., smart phones, tablets and smart glasses), base stations and cloud nodes. We assume a hierarchical cloud infrastructure that is composed of end offices (EOs), inter- mediate offices (IOs) and a Head Office (HO) [Bar15]. Base stations are equipped with a network gateway and also with a low complexity cloud instance, such as a cloudlet [Sat09]. Three different WSNs collect environmental information. Each WSN is com- posed of 25 sensors, uniformly distributed over a sensing area of 250x250 m^2.

Precisely modeling the processing capacity (in MIPS) and efficiency (in MIPS/W) of the smart city nodes is difficult, due to the limited information disclosed by network operators. Since this is out of the scope of this paper, we compute approximate values using information extracted from [Vis15] (i.e., cloud equipment), [Alt15] (i.e., smart devices), and [Xia10] (i.e., wireless sensors), which are presented in Tables 6.1 and 6.2. Note that we assume that the efficiency of cloud nodes increases at higher layers, thanks to the consolidation of processing tasks. Since the capacity and efficiency of smart devices vary considerably depending on the kind of device, we consider different realistic values in the simulations.

4. Conclusion

The future internet will combine the Internet of Things (IoT) and the Cloud. In this new paradigm, wireless sensors become cloud ready infrastructures and therefore, they can be orchestrated together with the rest of the IoT. In this paper, we formulate the service distribution problem (SDP) in IoT-Cloud net- works, referred here to as the IoT-Cloud SDP. This finds the optimal placement of virtualized functions over the network, taking into account the heterogeneous capacity- ties and limitations of end devices. We have implemented the IoT-Cloud SDP in three illustrative smart city services: augmented reality, autonomous sensing and actuation, and city monitoring. In the first example, the simulation results show that vFSN ad- justs the offloading decisions according to the processing efficiencies of end devices.

In general, we have shown that the IoT-Cloud SDP captures the tradeoffs that appear in IoT-Cloud platforms due to the heterogeneity of services, network technologies and devices. Then, using a fully virtualized approach, individual placement decisions can be taken in order to minimize the energy consumption of these networks, and hence reduce their cost and environmental impact.

5. References

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