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Smart Urban Data Space for Citizen Science

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Abstract: In smart cities, the number of citizen-operated sensor devices continues to increase. This development multiplies the amount of collectible data about our urban environment. Currently, many of those sensors are connected to proprietary cloud services with questionable effects on user privacy. Simply avoiding interconnecting those devices misses out on opportunities to collectively use data as a shared source of information. The city of Hamburg sponsored project Smart Networks for Urban Citizen Participation (SANE) aims at enabling citizens to connect existing sensors to create a city-wide data space while keeping control of devices and gathered data. Interconnecting these sensors enables all citizens to generate higher value information and thus improve their urban environmental awareness. In this paper, we describe the demo of our SANE architecture. The demo presents how citizens connect to the city-wide data space, how data can be collected, processed, and shared in a privately manner.

Keywords: Smart City, Internet of Things, Urban Sensing, Citizen Science, Distributed Data Processing, Data Governance

1 Introduction

As the number of privately owned sensors rises, so does the amount of data collected [BSE21]. There are various kinds of sensors like home weather stations, smart home devices, smart gadgets, and smartphones. This collected data is currently not fully exploited; most data is only used in closed data spaces or only available via local access. Data sent to a central server of the sensor provider is only shared with those who are part of provider's network. By relying on a central entity, a single point of failure and trust is given. Participants have no other option than to trust the central entity. In addition, these data spaces are usually limited to certain measurement types so that only specific queries can be made, making it challenging to link different information. SANE [BJK+19] focuses on closing this gap by providing an open and fully decentralized city-wide data space. Everyone can participate by collecting data, providing storage space or adding services that generate higher value information based on existing data. By opening this data space to the public, everyone can benefit from collected data: Citizens without own sensor

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hardware interested in their surroundings, businesses needing specific information without the capacity to deploy their own sensor network, and city officials. While collected data is the foundation of the SANE-network, own services can be developed and provided to process these data streams into higher-quality knowledge.

With a hands-on demo, we would like to present on how simple it is to join and participate to the SANE-network by adding new sensors. After the initial bootstrapping process of new sensors, we will show how participants can publish, process, and exchange collected data within the network. Therefore, an intuitive user interface is shown to display collected data, communication between participants, and generated information.

The following Section 2 gives a short overview of the SANE architecture. Section 3 describes the presented Demo. Section 4 gives a short conclusion and provides an outlook for future work.

2 SANE

SANE [BJK+19] establishes a city-wide and open data space[1]. Citizens can participate by connecting their sensors and publishing collected data, creating data processing services, and providing storage space to cache existing data on their hardware. The SANE framework provides interfaces to answer complex queries and explore existing data within the city.

The SANE architecture is partitioned into two main areas: *Field* and *network*. The field consists of sensors contributing new data to the SANE data space. For physical sensors, we provide a SANE-compatible reference implementation using the open-source operating system RIOT [BGH+18]. Additionally, SANE integrates external providers, e.g., via their APIs as virtual sensors, allowing them to connect existing data sources to the data space.

The network consists of interconnected nodes of varying capabilities operated by citizens. Nodes have multiple purposes, they connect to locally deployed sensors, act as gateways for collected data, and provide various services to the system and defining the functionalities of the SANE middleware. These include data provisioning, data quality assessment and data processing, access control, and user interfaces. Nodes may run any number of services, depending on their resources and user preferences.

Citizens can access the SANE platform's data via different interfaces, either tailored for visual user experience or direct machine communication. They allow for simple data exploration as well as complex queries connecting multiple data sources and measurement types. To achieve high accessibility, this will be as simple as browsing the WWW.

3 Demonstration Scenario

Our demonstration illustrates the SANE approach from a citizen perspective by showing the most relevant aspects of our system in multiple combined example scenarios. The scenarios cover a practical interactive sensing application, intuitive and secure sensor device bootstrapping, integration of heterogeneous public data sources, and citizen-controlled data processing.

To showcase the sensing aspect, we deploy ultrasonic and radar-based presence detection sensors in the rooms of the conference location. These sensors register when people move nearby

[1] https://github.com/sane-city

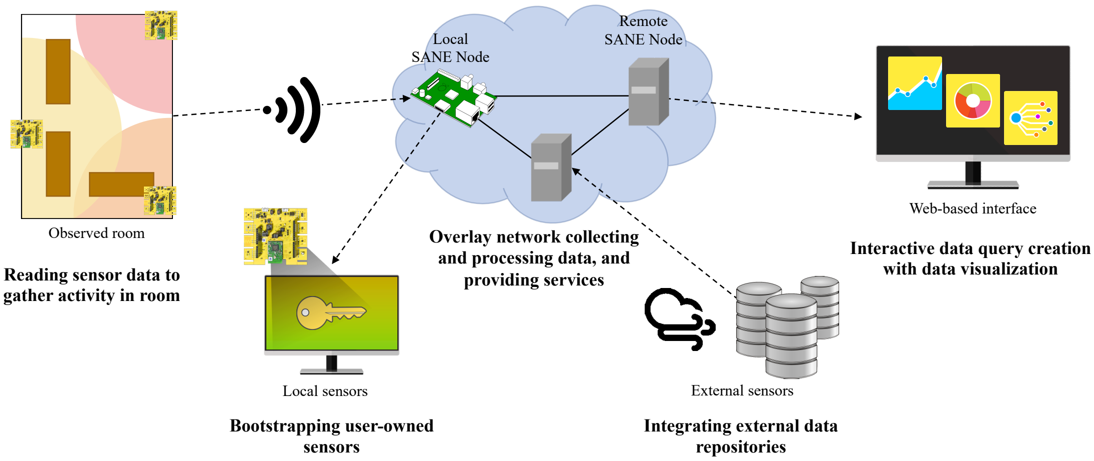

Figure 1: Demonstration setup showing locally deployed sensors, sensor bootstrapping, integration of external sensor data, and the interactive web interface to explore the SANE data space.

to indicate which rooms are occupied and how activity in different rooms changes over time. The sensors wirelessly connect to a SANE node based on a Raspberry Pi. This node provides collected data to the network, consisting of other devices, like servers and laptops. The measured activity can be viewed through a graphical interface, querying the data from the SANE middleware. It shows a heatmap of the activity in the rooms on a map of the area.

In a hands-on experience with our sensors, shown in Figure 1, we demonstrate how users are meant to securely add new devices that will later feed measurements into their digital data space. In this bootstrapping process, a sensor device provisioned with our SANE-compatible RIOT OS reference firmware is configured with initial parameters. The user may enter information like a custom name, location, etc., into a web form served by the node. Upon finishing this, a prompt with an animated colored screen appears which is used as an out-of-band communication channel to transfer bootstrap meta-data and cryptographic key material from the computer to the constrained sensor device. The latter uses a low cost RGB light sensing peripheral to receive the emitted color signals and then decodes the original data. Holding it up against the screen allows it to capture the data and configure itself accordingly to automatically and securely connect to the correct node. Afterward, the web interface lists the newly added device together with its metadata and associated data sources.

The data integration aspect is demonstrated by including data from publicly accessible external sources, like *luftdaten.info* and the *Klimabotschafter e.V.*. These show SANE's versatility for data source abstraction, allowing us to benefit from already existing crowdsensing initiatives and thereby expanding the data space available to SANE users. Our concept of virtual sensors highlights how this external data integrates with our data processing layer so that users can transparently interact with it.

For the user-facing component, we showcase a scenario that encompasses the interactive request and discovery of data via SANE. The individual SANE nodes autonomously discover each other and form an overlay network to orchestrate a distributed system. Within this node pool, each participant explicitly expresses trust towards other parties and shares data according to individual preferences. Data shared by others is usable as a resource for individual purposes by each trusted participant. A web interface is presented to the user for creating complex queries and data processing steps matching for certain conditions. The user may then utilize these elements to interact with available data and ask the system for related information. We visualize the queries and communication messages sent between nodes in the network to show how SANE triggers operations when interacting with it.

4 Conclusion and Future Work

With SANE, citizens can easily take an active role in their smart city by participating in data collection and use. Our approach provides an alternative to closed, commercial devices and data hogging cloud services by giving users full control of the devices that collect their data and the systems that process and share it. Data collected from a user-operated sensor is consequently owned by the same user unless it is explicitly shared with others. SANE uses virtual sensors to integrate individually shared and public data sources into a data space that can be combined with private data to serve as the foundation for custom data-driven applications and services. Citizen participation is an important factor for the success of different smart city initiatives [BJ16]. Full control over devices, infrastructure, and data processing steps allows users to obtain first-hand experience and improves visibility of aspects that are commonly hidden from users. This additional level of active involvement is considered to eventually raise awareness and acceptance, which is needed for the broad adoption of a participatory distributed smart city infrastructure.

For future work, we aim to focus on efficiently address existing information within our distributed network. Here we are going to look at Distributed Complex Event Processing, fitting the event-based nature perfectly. Furthermore, we are looking into improving data quality by evaluating incoming data and quantifying the trustworthiness of values to increase the confidence in information provided by SANE's open data space.

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