Poster Abstract:
A Privacy-Enabled Platform for COVID-19 Applications

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ABSTRACT

We present our experiences in adapting and deploying TIPPERS[1], a novel privacy-enabled IoT data collection and management system for smart spaces, to facilitate the monitoring of adherence to COVID-19 regulations in a university campus and a military facility.

CCS CONCEPTS

• **Information systems → Data management systems**; • **Security and privacy**;

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1 INTRODUCTION

As organizations reopen from mandatory lock-downs caused by the ongoing COVID-19 pandemic, regulations and policies have been formulated and put in place to ensure adherence to public health guidelines - the key goal being to limit spread of the virus within organizational spaces. Large organizations, including universities (e.g., UC Irvine) have defined custom policies, directives, and protocols to enable safe reopening of facilities for onsite work. These include regulations on physical distancing, building occupancy, hybrid in-class and online instruction; additional protocols for regular testing of staff and students and contact tracing have been established in concert with local public health authorities.

We describe a technology-based solution to help organizations monitor adherence to occupancy-based regulations, as well as, empower individuals to check for exposure to the virus within the organization's premises while still ensuring strong privacy properties. Our approach leverages TIPPERS [2], a novel general-purpose sensor data collection and management system for smart spaces, built over the past five years. A bedrock principle that serves as the core foundation of TIPPERS is **privacy by design**. In TIPPERS, data collected from sensors is subject to strict privacy policies that exploit a range of privacy enhancing technologies ranging from device-id randomization, encryption, to differential privacy. In the following, we first provide a brief introduction to TIPPERS, followed by a description of two deployments of TIPPERS with applications related to COVID-19.

[1] https://tippers.ics.uci.edu/covid19-apps

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2 TIPPERS

TIPPERS abstracts the underlying sensor infrastructure by translating between the world of IoT devices (i.e., sensors, actuators, raw observations, etc.) and the world where people act (i.e., interactions of people, and spaces, phenomena, etc.). The system is based on a domain model that represents both these layers (devices, applications) and enables users/developers to interact with high-level semantically meaningful concepts. It also includes ontology-based translation algorithms to convert user requests at the high-level, (e.g., *retrieve spaces with occupancy higher than 20% of capacity*) into actions on the specific underlying device infrastructure. TIPPERS, thus simplifies the development of smart applications and facilitates portability as applications are built on high-level semantic concepts, not at the device level. Furthermore, the semantic view simplifies the definition of privacy policies allowing users to express what they want to protect, e.g., *do not capture my location when I am with John in a private space during working hours*. TIPPERS uses such privacy policies to constrain and guide its data collection, storage, and sharing practices.

The TIPPERS system incorporates *virtual sensors,* wherein streams of sensor data can be used to create streams of inferences. For instance, a virtual sensor can translate connectivity data (e.g., connectivity logs from WiFi access points (APs)) into occupancy of different spaces over time. A key component of the TIPPERS architecture is the *mediation module* that appropriately stores sensor data into one or more underlying database/storage technologies (e.g., allowing the use of multiple database platforms). Mediation enables TIPPERS to store data in different systems based on the characteristics of the data, its security requirements, and the type of queries that need to be executed. In particular, TIPPERS stores sensitive data in secure databases (supporting encrypted representation) and the mediator automatically transforms TIPPERS queries to execute on such databases.

3 COVID-19 MONITORING DEPLOYMENTS

TIPPERS can be used in multiple scenarios as it has a generic implementation and is capable of handling data from various types of sensors. It also provides abstraction and easy-to-use REST APIs to developers for rapid application development. Below we describe two TIPPERS deployment with different setup and applications (see Figure 1).

3.1 UC Irvine Campus

UCI has a large scale campus-wide deployment of TIPPERS providing a variety of location-based services based on exploiting WiFi connectivity events from personal devices carried by individuals captured

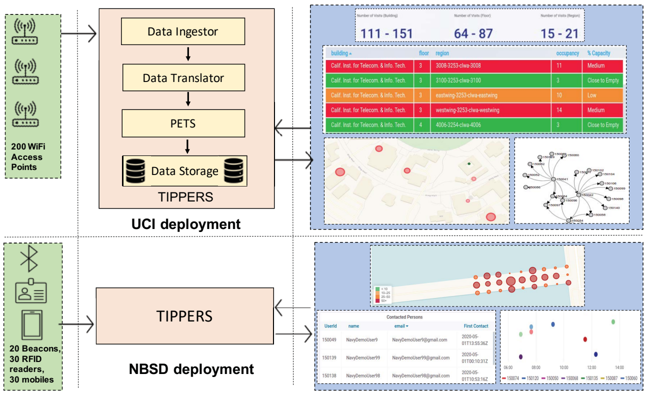

Figure 1: Deployments of TIPPERS.

by the campus network. Such events (i.e., ⟨MAC address, time stamp, wap⟩) correspond to the MAC of the connected device, the timestamp when the connection occurred, and the WiFi AP to which the device connected. Since APs are at fixed locations, connectivity events can be used to locate a device to the region covered by the AP. TIPPERS includes ML code to locate individuals to finer (e.g., room level) granularity [1]. Location data, appropriately encrypted, is used to build several applications to help the UCI community with COVID-19. **Occupancy adherence** assesses if the community is indeed implementing occupancy and social distancing advisories suggested by the campus administration. As shown in Figure 1[2], it has the ability to monitor when regions such as classrooms, meeting spaces, and shared offices exceed desired occupancy levels, identify locations within the organization where there has been a high rate of people passing by, and hotspots where groups of individuals tend to congregate. Such monitoring allows organizations to conduct an in-depth analysis to reveal potential exposure hotspots, inject interventions (dispatching supervisors who can nudge individuals to relocate) or make remedial operational changes such as scheduling more-frequent sanitization where needed. TIPPERS includes data cleaning algorithms to account for multiple devices carried by individuals (that would result in over-counting), as well as, sporadic and noisy nature of the WiFi connectivity data in computing occupancy. **Exposure Tracing** enables individuals to share information (without revealing their identity) to empower TIPPERS to determine location (and time) when those individuals were in the region. Exposure tracing helps identify regions at the organization's premises where exposure by others to those infected could have occurred. It also includes mechanism for individuals to check (again, without revealing identity) if they were overlapped with an infected individual in a region. Exposure tracing is extremely useful to help focus and target contact tracing efforts, that are often time-consuming, by rapidly and accurately determining those who potentially may have come in contact with an infected individual.

3.2 Naval Base San Diego

In the TIPPERS demonstration deployment at the Naval Base San Diego (NBSD)[3] (see the bottom of Figure 1), the goal was to perform more fine-grained tracking of people. The space, a pier at NBSD, was smaller than the campus and highly instrumented with WiFi APs, Bluetooth beacons, RFID readers, and smartphones with a TIPPERS client application (capturing GPS readings among others). While privacy was not as big of a constraint compared to UCI, the challenge was the fusion of sensor data to accurately locate individuals in a robust manner. Requirements about social distancing (in terms of number of meters between people) had to be fulfilled.

The experiments performed (tailored towards COVID-19 mitigation) involved 30 Navy personnel, who served as participants, and performed a series of scenarios as they moved between different zones on the pier. Data was passively captured using the WiFi infrastructure and actively using the TIPPERS client application on the smartphones. Then, the data was correlated by TIPPERS to locate individuals in the different zones of the pier (each zone had been defined in the system to cover a small area). In this process, ML software components in the system were used to triangulate the location of a person given the signal obtained from the Bluetooth beacons and WiFi APs when GPS data was unavailable. Finally, the information of multiple individuals had to be correlated to check whether social distancing criteria were met.

TIPPERS demonstrated the ability to correlate and display tracking data in near-real-time, exhibiting its potential for use in COVID-19 applications such as: **Quarantine zone verification and access restrictions**, which monitor which areas have been visited by infected individuals and alerted when an infected individual visited a safe location and **Verified "secure bubble" transfer**, in which a unit (e.g., a group of individuals) have to be protected and alerts have to be triggered if any of its members came in contact with an infected individual. In the experiments, the system presented high accuracy and robustness to different scenarios thanks to the number of sensors deployed and the internal algorithms to correlate their captured data.

4 CONCLUSION

Our efforts in adapting TIPPERS to support COVID-19 applications has met with significant interest both within UCI campus and the US Navy[4]. TIPPERS occupancy apps are in operational use in 4 buildings as part of the reopening strategy. Given TIPPERS support for semantic abstraction, sensor-agnostic, general purpose design, and support for privacy technologies, adopting it to COVID-19 applications was relatively straightforward: mainly requiring writing simple SQL queries and GUIs to display results. We are currently working with various stakeholders to support the specific needs of different types of buildings and spaces both at UCI and at other organizations that are planning to adopt the system.

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[2]The figure shows the spaces that do not adhere to the social distance criteria in red.
[3]https://www.dvidshub.net/news/374318/navwar-trident-warrior-team-assesses-new-tracking-technology-covid-19-mitigation
[4]https://tippers.ics.uci.edu/highlights