Reconfiguration and Integration of IoT in the Context of Business Process Management

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Abstract

The abundance of the Internet of Things (IoT) has enabled their massive use and adoption in various application domains, such as a Smart City, where they provide data and offer services intending to improve the quality of citizens' life. This paper describes a possible solution for allowing Business Processes (BP) of a Smart City to have an insight in visitors' and citizens' mobility, and to reconfigure BP-relevant IoT devices automatically based. We base our solution on citizens with social media accounts that may act as a "social sensors" capable to produce data and respond to relevant events on social media. In that direction, we extend our Business-to-Social (B2S) platform with ability to reconfigure IoT devices and serve as a two-way bridge between social and IoT worlds. Finally, we present an application of this system managing public mass events in a Smart City by allowing citizens and visitors to adapt Smart City services according to their mobility.

Keywords — Smart City, Business process, Internet of Things, Social media

1 Introduction

In 2007, the total number of human population in urban areas has exceed 50 percent, and it is expected that this number will rise to 70 percent until 2050 [1]. All around the world cities are trying to improve transportation linkages, provide efficient land use, and offer high quality services that would have positive impact on the economy and quality of life [2]. Clark et al. states that the future for municipalities around the world lies in the concept of Smart Cities which will use Information Communication Technologies (ICT) to solve current and future challenges [3]. Deloite identifies three cornerstones of Smart City: disruptive technologies, data and people [4]. The Internet of Things (IoT) is the most frequently used disruptive technology and one of the main driving forces of a Smart City. IoT devices produce data and offer services that could improve the quality of citizens' life. The abundance of IoT devices has enabled their massive use and adoption almost everywhere due to their small size, processing power, availability, and affordability. Data generated in a Smart City can be used for modeling and predicting urban processes and simulating urban development [5]. Although ICT is often seen as a main wheel in a Smart City, it must also involve human capital and smart people [6]. According to the Deloitte [4], Smart City also needs smart governance and smart people besides technology. Hollands [6] states that the crucial factor in any successful community has to be its people and how they interact. Bauman [7] sees any citizen with a social media account as a possible "social sensor" capable to produce data and respond to relevant events on social media.

Smart and sustainable mobility is one of the important factors in any city that affects a number of city's ecosystems. Successful management of visitors and citizens' mobility ensure eliminating traffic bottlenecks and congestion that are common problems during popular events or unplanned occasions. To address these problems, a Smart City must rely on all available data sources, including social media and IoT. Social media are used to enhance communication with visitors and citizens with the aim to detect and analyze interest in specific events in advance, as well as their planned attendance at the event. Consequently, Smart City automatically reconfigures its services towards respondents' engagements. Furthermore, service reconfiguration includes automatic adjustment of Variable Message Signs (VMS) that manages users' mobility across the city. VMS can contain parking guidance info, guide people to alternative streets or inform about changing traffic.

The paper describes a possible solution for allowing a Business Process (BP) of a smart city to track visitors' and citizens' mobility using their actions on social network/media, and, based on that, automatically reconfigure BP-relevant IoT devices. In that direction we extend the Business-to-Social (B2S) platform [8] with the ability to reconfigure IoT devices and serve as a two-way bridge between social and IoT world. IoT devices used in our experiments are low cost wireless micro-controllers that are open-source, extensible, cross-platform devices without operating system capable to control sensors and to actuate with low power consumption. Under certain conditions devices are reconfigured using Over The Air (OTA)[1] approach which allows fast deployment of new functionalities to remote devices that runs on NodeMCU firmware. Communication between these devices and B2S is through secured Message Queuing Telemetry Transport (MQTT) protocol [2] and HTTP REST. We present an application of this system with managing touristic events in a Smart City by allowing citizens and visitors to adapt and refine Smart City services related to mobility during mass events.

The paper is structured as follows. Section 2 gives some definitions and related work on bridging business world at one side and the IoT and social world, at the other side. Section 3 presents our solution that continues with implementation in section 4. Finally, some concluding remarks are given.

2 Background

This section provides an overview of the related work on IoT and citizen sensing in Smart City along with some definitions. Then, it concludes with some conclusions about automatic IoT reconfiguration in favor of Smart City services.

2.1 Some definitions

Smart city. A plethora of definitions exist over what smart city is or should be. From a system point-of-view, smart city is a mix of digital communication networks, ubiquitously embedded intelligence, sensors, and software [9]. From a conceptual point of view, Nam and Pardo [10] identify people, community and technology as three conceptual dimensions to transforming life and work in a city, to explore human capital,

[1] www.ioti.com/security/secure-over-air-ota-technology-remote-management-iot-solutions.
[2] mqtt.org.

and to support of government and policy, respectively. In the context of this paper, a usability point-of-view, defines smart city as *"a developed urban area that creates sustainable economic development and high quality of life by excelling in multiple key areas: economy, mobility, environment, people, living, and e-government"* [11].

Internet-of-Things. The unique definition of what IoT is or should be. A good overview of characteristic and enabling technologies can be found in [12]. Characteristics include distribution, interoperability, scalability, resource scarcity, and security. And, enabling technologies include sensing, communication, and actuating. In the context of this paper, the definition given from a data perspective by Qin et al. [13], emphasizes that *"Computers will be able to learn and gain information and knowledge to solve real world problems directly with the data fed from things. As an ultimate goal, computers enabled by the Internet of Things technologies will be able to sense and react to the real world for humans"*.

Social world. An unpredictable dynamic world, whose actors are stakeholders (usually anonymous) and machines.

Social machine. An emerging paradigm that relies on social computing and shall be the result of the convergence of three main visions: (*i*) *Social Software* (as its foundations), (*ii*) *People as Units of Computation*, and (*iii*) *Software as Sociable Entities* [14].

Business process. BP is *"a set of logically related tasks performed to achieve a defined business outcome"*, as defined by Davenport and Short [15].

2.2 Related work

Valdivia et al. [16] applies sentiment analysis to data collected from the popular touristic website TripAdvisor. They have developed an analysis for studying the matching between users' sentiments and automatic sentiment-detection algorithms. Michele et al. [17] analyze the feasibility of using IoT approach and proposes a specific architecture for a sustainable tourism. Their aim is to optimize the movement of cruise ship tourists by taking into consideration factors such as transport information and queue time. Cranshaw et al. [18] study social dynamics in a large scale city by introducing clustering model and research metodology based on the data collected on social media in their Livehoods project.

Some initiatives combine both IoT and social media. Badii et al. [19] work on CityScripts that combines social networks and IoT in a SC. CityScripts uses social networks to collect streams from Twitter in combination with data from different sensors and actuators. Another example of a SC framework, which uses near real-time IoT data and social media, is CityPulse [20]. This approach is based on analyzing social media streams from Twitter focuses on content analysis using machine learning. Besides, there is no correlation with locations which could lead to false results.

ZenCity[3] platform aggregates and analyzes citizen sentiments and provides feedback for local government. In essence this platform is used to analyze different data streams containing clues about problems experienced by citizens, what they care about and how they feel about governments actions. Algorithms, such as classification, sentiment analysis, anomalies and geolocation are used for AI to get more focused, real time view of how citizens feel.

[3]zencity.io.

Although some of these projects include both social and IoT world, there is no two way communication that includes automatic reconfiguration of IoT devices as a result of adapting Smart City services.

3 Connecting the business, social, and IoT worlds together

B2S platform is a social machine that serves as a glue that connects Business processes to Social world and IoT world, as well. The social world we are referring to consists of people that are using social media to generate data that is used for later analysis. On the other hand IoT world consists of all IoT devices such as sensors and actuators that are available in a Smart City. Here we categorize IoT world in *internal IoT* that contains devices owned and maintained by a Smart City, and *external IoT* (e.g., wearables and smart phones) that contain devices that are not controlled by a Smart City, but rather by third party owners. The focus of this paper is on *internal IoT* devices, that sometimes could be constituents of business processes.

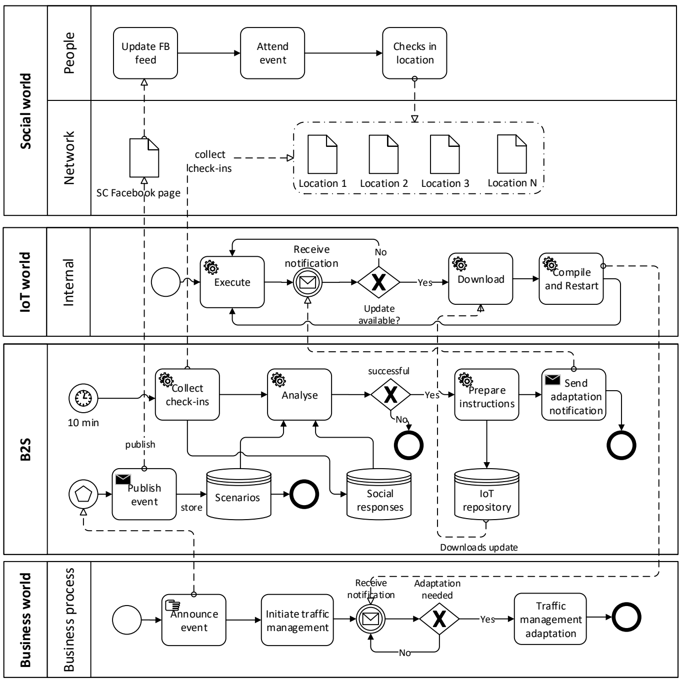

Figure 1: B2S connecting different worlds together

The previous version of B2S platform described in [8] used IoT world as a data source only, where data sensed from IoT devices are collected along with data from social networks and based on defined scenarios different new social actions were published. Real life situations shows that it is not enough to collect sensed data only, but it is also deemed necessary to control them too. Our approach to controlling IoT devices is not only in form of sending instructions that will IoT devices follow, but also in form of their automatic reconfiguration towards Smart City needs and based on other data sources. To overcome mentioned limitations we extended B2S platform by adding capability to control and reconfigure IoT devices and thus enabling two way communication to both social and IoT worlds.

Figure 1 shows the dynamics of task execution in Business Process Modeling Notation (BPMN) between a BP, social world and IoT world via B2S platform. Business process represents organization of a mass event in Smart City. Smart City decides to announce event on social networks via B2S platform along with storing some events' meta-data in B2S repository that will be used in later analysis. Smart City also initializes specific traffic management for that event that includes traffic lights, parking and VMS to meet the events' demands and expectations. In regular time intervals B2S platform collects the data from social networks that include number of citizens/visitors check-ins in locations of interest at that time and stores them for later analysis. B2S then analyses response to event, and in case that there is detected higher response than expected, it prepares a new set of instructions for reconfiguration of IoT devices. The IoT devices are then alerted about the pending update, and after downloading the update, they compile it and restart themselves with a new set of instructions. Reconfiguring these IoT devices leads to adaptation of traffic management system in Smart City.

4 Implementation

Figure 1 shows how B2S is used to bridge the Social and IoT world. Almost all of the process, except publishing an event on Facebook page, is done automatically. This section explains how it is done.

4.1 Tapping into the social world

B2S dashboard allows the city manager to create and post details about the event on Smart City Facebook[4] Page via *Facebook SDK v5 for PHP*[5] that makes requests to Facebook Graph API[6]. While creating the event, a manager defines the location of an event, the starting and ending time of an event and locations of interest that will be a subject of check-in analysis. All collected information is stored in *Scenarios repository* and will be used in later analysis.

In order to obtain the effect of the call to an event, we aim at collecting the "real-time" data about citizens/visitors mobility by collecting their check-ins in public places that are at, or near the location of the event, and are defined while creating the event. Due to recent changes in its privacy policies, Facebook disallows access to the details about specific check-in in these locations, but allows collection of total number of check-ins at the time of request. In order to overcome this restriction we created an "in-house" PHP program that uses *Facebook SDK v5 for PHP* to access the total number of check-ins for each location of interest every 10 minutes, using a Cron[7] job. It stores such data in the MySQL relational database ensuring that chronological order of check-ins is preserved for each location.

[4] www.facebook.com/SmartCityTouristicOrganization.
[5] developers.facebook.com/docs/reference/php/.
[6] developers.facebook.com/docs/graph-api.
[7] en.wikipedia.org/wiki/Cron.

To make conclusions about the changes in citizens' mobility, B2S uses homogeneous time intervals for calculation and analysis in order to detect growth of number of visitors. The length of time intervals that are analyzed in the B2S platform is set to one hour. B2S counts check-ins in all locations for each time interval to be able to detect total increase of visitors/citizens number during the event.

4.2 IoT world reconfiguration challenges

To test reconfiguration of IoT, we used micro-controllers based on ESP8266 chip without operating system. The idea is to update its software automatically via OTA approach without need for direct serial connection. To allow their reconfiguration EPSLoader v2[8] is extended and integrated into B2S platform. It enables B2S to communicate with micro-controllers via MQTT instead of HTTP, that consumes more power and is less efficient. IoT reconfiguration consists of two stages, one is related to IoT device installation, and the other is for preparation of the software for reconfiguration on the B2S side.

IoT device installation firstly ensures that NodeMCU firmware is installed on each device along with necessary modules, and then uploads Lua scripts that allows communication with B2S platform via MQTT protocol and downloading new scripts upon message received.

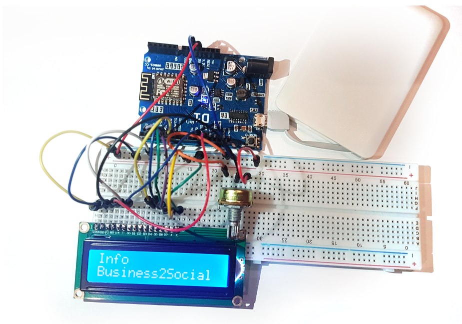

Figure 2: Wemos D1 R1 and 16x2 LED display connected to external battery

After preparing the new software for update, B2S publishes MQTT message via MQTT topic "update" to all of its subscribers. IoT device Wemos D1 R1[9], that we used in this experiment, is subscribed to the topic "update" and upon receiving that message issues HTTP request for downloading the new update from B2S platform. After the update is downloaded and compiled, the Wemos D1 R1 device reboots with the new software. In this demo application we use 16x2 LED display wired to the Wemos D1 R1 via the breadboard, that can display different messages as a result of OTA reconfiguration (Fig. 2).

4.3 Experiments

Algorithm 1 shows the necessary steps in automatic process of collecting check-ins from locations around the event and their analysis, which can trigger the reconfiguration of IoT devices according to analysis results.

[8] github.com/kovi44/NODEMCU-LUA-OTA-ESP8266.
[9] wiki.wemos.cc/products:d1:d1.

Let $locations = \{l_1, l_2, ..., l_n\}$ be the set of n locations of interest that are analyzed, and $timeintervals = \{t_1, t_2, ..., t_m\}$ is a set of homogeneous m time intervals $t[from, to]$ that are tracked for each location. For each location let $checkins_{l_i} = \{c_{l_i t_1}, c_{l_i t_2}, ..., c_{l_i t_m}\}$ be a number of check-ins in different time intervals, where $i = \{1, ..., n\}$. In order to have a comprehensive insight in the effect of the events on visitors mobility and check-ins, we sum up all locations' check-ins in the same time interval $sum_{t_j} = \sum_{i=1}^{n} c_{l_i t_j}$, where $j = \{1, .., m\}$, and place them in the set $totalcheckins = \{sum_{t_1}, sum_{t_2}, ..., sum_{t_m}\}$. Starting $E_{t_{start}}$ and ending $E_{t_{end}}$ time of an event is used as a time interval in which all new check-ins are collected and analyzed with aim to detect higher rate of check-ins than usual. Therefore, the minimal number of check-ins that is used for comparison is calculated by applying median to the set of total check-ins, $min = median(totalcheckins)$. If number of check-ins in event time frame are higher than usual, system triggers IoT reconfiguration with aim to adopt traffic management system to fit smart city needs.

Algorithm 1 Algorithm for assessing results and IoT reconfiguration

```
for all locations as l do                                  ▷ Loop through all locations
    for all timeintervals as t do                          ▷ Loop through all time intervals
        checkins[l] = count(c[l][t])                       ▷ Check-ins in a location for time interval
        sum[t]+ = count(c[l][t])                           ▷ Sum of check-ins for the same time interval
    end for
end for
for all sum as s do
    totalcheckins[] = s                                    ▷ Create list of sums
end for
min = median(list(totalcheckins))                          ▷ Calculate median from list of sums
if curentTime > eventStart and min < checkins(Event) then
    prepareNewUpdate()
    alertThings()                                          ▷ Inform things about pending update
end if
function ALERTTHINGS
    downloadUpdate()
    compile()
    restart()
end function
```

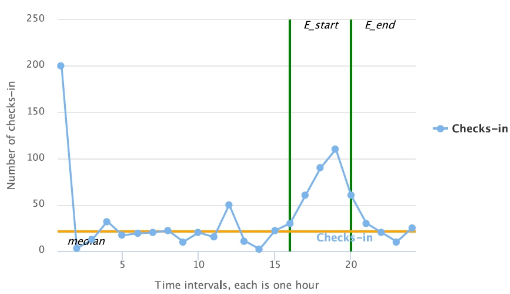

Figure 3: Checks-in during the last 24 hours

Figure 3 shows more comprehensive insight into data produced by applying Alghoritm 1 for 24 hour time interval. Each dot on the x axis refer to the number of all check-ins during one hour, the horizontal orange line shows median which is used as a filter for easier detection of higher visitors response, vertical lines e_{start} and e_{end} refer to the starting and ending time of the event.

5 Conclusion

IoT devices are everywhere around us due to their affordability and abundance. We present new, extended version of the B2S platform that serves as a social machine that glues Social world, IoT world and business processes in a Smart City. The new B2S platform allows two-way communications to both IoT and Social worlds ensuring that their whole potential could be used. Its benefits are presented in the use case of managing citizens mobility during a mass event, where B2S collects the number of check-ins from social media originating at different locations of a Smart City at regular time intervals, and processes and analyzes them along with events' metadata. If IoT device reconfiguration is needed, a new software is prepared automatically and IoT device that should be reconfigured are alerted. Upon downloading the new software, device compiles the code and reboots itself with the new configuration. This ensures that devices could completely change its behavior and functionality according to specific situations. The devices used in this experiment include micro-controllers based on ESP8266 chip with no operating system. Developing business rules that would evaluate whether the IoT reconfiguration based on social media and other sources, is successful or not, is out of the scope of this paper and it is left to future work.

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