IOT Applications In Agriculture

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Abstract- *Rural areas face a number of similar issues in the domains of agriculture, connectivity, water, transport, health and education etc., which calls for potentially similar solutions to be directed towards solving these issues. The intention of this research is to investigate the potential contributions of internet of things technologies (IoT) towards poverty reduction in these rural areas, in line with the needs identified in these communities and with emphasis on agriculture. The paper identifies examples of IoTs to mitigate the agricultural needs of these communities for the domains of crop farming, weather forecasting, wildlife management, forestry, livestock farming, market identification and rural financing.*

Keywords- agriculture, rural development, internet of things

I. INTRODUCTION

Internet of Things (IoT) characterizes the interconnection of different devices with ubiquitous accessibility and built-in intelligence. IoT is already reshaping the way we interact with devices and providing us with the novel networking and socializing capabilities through intermediary devices. So much so that it will soon transform our lives into a hyper-connected cyber-physical-social environment [1]. The potential devices include smartphones, bio-nano-things, body sensors, smart tags, wearable devices, embedded objects, and traditional electronic gadgets. These heterogeneous IoT devices have distinct connectivity and interfacing demands as well as service quality requirements [2]. Within the context of Social Internet of Things (SIoT), which is a specialized subset of IoT, the heterogeneous devices not only connect and interact but also socialize and collaborate with each other to achieve some specific task(s). This kind of social interaction requires cooperation among IoT devices which is the essence of SIoT.However, it cannot be truly realized unless built-in support is provided inside the operating systems (OSs), device firmware, or other software running on these IoT devices [3].Specifically, an Operating System (OS) enables ease of device usage by offering portability, threading support and access to online development libraries. Thus OSs can facilitate better design and implementation of innovative social IoT applications [4]. Moreover, IoT developers mostly prefer to use an OS on IoT device(s), even in a single application entity, as it enables ease of application development along with other handy and extensible features. Particularly in SIoT application scenarios, these IoT devices are often heterogeneous and equipped with a variety of hardware architectures; hence they should have the necessary capability to efficiently run the potential OSs. Though, the choice of suitable OS for a specific hardware device in IoT application is usually a critical challenge. In case of resource-constrained environments, the desire for optimal selection of software (e.g., OS) as well as hardware (of specific type) resources become even more crucial to support dynamic social collaboration among devices in IoT applications.

An appropriate selection of OS for a unique hardware will result in rapid development of time-efficient and user-friendly IoT applications. It will particularly facilitate the inter-device communication within SIoT applications to improve the performance of interacting devices and efficacy of service delivery. Further, to allow interaction not only among devices with similar hardware architectures but also with dissimilar ones, OSs should incorporate the corresponding enabling features as well. For instance, the implementation of standardized communications interfaces within OSs ensure the efficient device collaboration and hence reduce the intermediary commute delays. Moreover, an OS can also play its role in improving the utilization of various resources, ranging from hardware computational resources to software resources along with other resources such as a battery and storage. Thus, OSs can act as enabling platforms for creating a cooperative ecosystem of all heterogeneous yet interactive devices in the future hyper-connected social environments. However, existing literature does not take into consideration the functionalities of OS in tandem with hardware architectural capabilities. Although, it is inevitable for the efficient development of many IoT applications, especially where extensive social collaboration is involved. In fact, most of the research studies on IoT software and/or hardware platforms have overseen this essential requirement of matching the OS architectures to that of hardware architectures, which may lead to the underperformance of both, especially in constrained environments.

The currently available research work in the literature on OSs can be broadly classified into two major areas including Wireless Sensor Networks (WSNs) and IoT.

A. WSNs

In last decade or so, many research studies are conducted on the suitability of OSs for constrained environments [11]-[14]. The design of a lightweight Linux Security Module (LSM) is presented in [15] which claims implementation with minimal changes in the kernel. The LSM module design ensures generality and its access control for other modules. In [16], the performance analysis of tailored Linux OS on different microcontrollers is provided. The paper discusses the memory management and processes running in the tailored Linux design while also describing some key differences in the kernel with that of Desktop Linux. While the majority of other survey papers on constrained OSs are domain oriented as they describe features and layers of OSs which are appropriate for particular domains. Primarily these surveys are focused on WSNs.

For instance, a research paper in [7] has discussed the support for different programming languages framework along with the networking protocols supported by various OSs for WSNs. The hardware platforms on which these OSs can be ported are also figured out. Authors discussed multiple OSs while considering various features required for WSNs. These features are discussed in the light of architecture, programming model, scheduling techniques, memory protection and management, communication stack, resource sharing algorithms and real-time capabilities. This research work also considered the requirements and key challenges for any OS to run in domain-specific hardware in constrained environments. The software stack of the OSs are taken into consideration and availability of some core libraries in software development kit (SDK) is investigated as well.

Smart Shopping Mart Retailing

A customer enters in a shopping mart premises and turns on her *smartphone*. The smartphone integrates with and shows the shopping mart App which, after authenticating the customer from a *smart camera* deployed at the mart entrance, generates her personal user profile. The smartphone App interacts with a *refrigerator* at home to provide a check-list of required grocery items. It then collaborates with the *local server machine* to find and notify the location of these items to the customer through *sensors* and *RFID tags*. Once the customer selects and pick up the items, the invoice is generated from *local server* on her smartphone and customer may then proceed with the amount payable using her online credit card.

B. Healthcare and Telemedicine

Hospitals and healthcare centers enabled by IoT vision can provide better medical facilities to rural areas, and patients are monitored in real-time, their medical records at *cloud server* will be accessed with immediacy and treatment is suggested straight away. *Smart medicine-box* can remind patients their dosage and interact with *body sensors* to efficiently monitor and plan any change in the dosage [49]. At highways, *smart cameras* collaborate with each other to provide quality live streaming of an accidental event to a nearby hospital. On-road/air ambulance get instantly notified to evacuate the patient(s) in critical condition, while the *sensors* installed in the mobile health vehicles may collaborate with the *cloud server* and/or *body sensors* to instantly adjust the vehicle's medical apparatus parameters in the best manner according to the patient's medical history.

C. Intelligent Multimedia Streaming System

A user is traveling in a smart driverless car, and he wants to entertain himself by watching a movie. A virtual movie catalogue on car's *microHD screen* provides the latest recommendations anticipated by the discussion on trending movies among user's friends on social media. It may also collaborate with the personal belongings of the user such as his *iPhone*, and *laptop* or *multimedia system* at home, thus forming a personalized cloud. The cloud fetches and analyzes the historical meta-data to identify various movies in which a user may be interested in, and display them on *microHD screen* through collaborative tethering services. Meanwhile, *smart sensors* installed in the car are managing driving parameters and controlling navigation via live maps. These *sensors* continuously monitor car's accelerator speed and collaborate with *microHD screen* to allow dynamic adjustment of the data rates and bandwidth of multimedia streaming according to the speed of the car to ensure high-end real-time experience.

D. Smart societal interaction

A smartphone App can be developed that learn about friendship of two individuals from social networks while they are roaming in a common leisure place. It can track their location through the collaboration of on-location *camera devices*, and notify them on their *smartphones* that they can potentially meet with each other while also suggesting them a suitable socializing venue. Alternatively, *camera devices* in a restaurant or a gym collaborate with each other to monitor the behavior of regular visitors (but at completely different timings). This information is stored at the IoT gateways and after learning from social networks about the visitors who are living in nearby vicinities, suggestions can be made on smartphones that they can socialize with each other.

E. Traffic surveillance and road safety

A smart traffic monitoring App can combine the information provided by connected *vehicles*, driver profiles, *road sensors* reporting occupancy patterns and disseminate this information through IoT *edge devices* in a real-time manner to reduce or avoid traffic congestion. Another possibility is that a roadside *surveillance camera* detects an ongoing theft situation in the street, generates an *alarm*, and may also provide video footage to alert the *mobile police vehicles* to take necessary action.

All of these example scenarios accentuate that by employing SIoT concept, the device-level interactions and collaborations can provide new socialization opportunities for different IoT devices as well as for their owners. It can contribute to identifying new information from ordinary data streams and may also facilitate in discovering knowledge out of it. Moreover, the various interacting devices mentioned above such as *smart cameras, sensors in the refrigerator, RFID tags, body sensors, smart medicine-box,* and even personal gadgets such as *smartphones, laptops* or *multimedia systems* can eventually develop relationships with each other based on the level of trustworthiness. The relationship establishment thus creates further possibilities such as an increase in network navigability, scalability, device as well as service discovery, service composition, etc., among other exciting possibilities.

However, these prospective SIoT possibilities can be realized and incorporated into IoT devices only if they exhibit the corresponding capability within their hardware and/or software components. For instance, the establishment of trustworthiness among devices in various SIoT use case scenarios is reliant on the computational capability of their hardware. Similarly, heterogeneous IoT devices can only interact and identify the relationship with each other if they have the rich type of communication interfaces available inside the hardware which in turn play a crucial role in extending the network scalability. However, any communication interface itself requires the matching support from the OS(s) driving the hardware both in the form of communication stack and protocols. In fact, the support of many other features of hardware architecture or the software program embedded within them is required for other SIoT components as well. Hence, the significance of key features of hardware architectures and that of OSs is recognizable to enable socializing possibilities among IoT devices and resultantly, the OS-to-hardware architecture feature-mapping turns out to be vital in achieving all these SIoT objectives.

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