Greeves: A Smart Houseplant Watering and Monitoring System

Er. Vineet Biswal, Er. Hari M. Singh, Dr. W. Jeberson, Er. Anchit S. Dhar

***Abstract*—Greeves (green leaves) is a smart Houseplant Watering and Monitoring system that monitors and tracks environmental conditions, helping the plants thrive. The Garden Sensors gather and analyze data about changing weather and soil moisture conditions and then connects to the user's Android phone with timely alerts. Also, the system includes a .Net Application which runs on a Microsoft Windows Computer which can be used to monitor the plant's conditions at user's workplace. It continuously monitors the conditions and alerts the user to the changes that require immediate action. Unlike pre-set sprinklers, the Greeves Water Valve automatically controls the existing water system based on data collected by the Garden Sensor and adapts to every change in the plant's requirements.**

The paper describes the architecture and methodology used to integrate different platforms together to develop a working system using Cloud Computing. It integrates Android, Windows, Arduino and Thingspeak Cloud together to work in tandem making the system achieve its set goals.

Keywords: Houseplant Monitoring; Internet of Things; IoT; Cloud Computing; Automated Gardening.

I. Introduction

The Internet of Things (IoT), sometimes referred to as the Internet of Objects, will transform everything—including ourselves. This may appear like a bold statement, but consider the impact the Internet already has had on education, communication, business, science and humanity [20]. Clearly, the Internet is one of the most important and powerful creations in all of human history. Internet of Things (IoT) [10] is an integrated part of Future Internet and could be defined as a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network. The term of IoT was first used by Kevin Ashton in 1998, has gained more and more developments today [5]. In the IoT, 'things' are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information 'sensed' about the environment, while reacting autonomously to the real world events and influencing it by running processes that trigger actions and create services with or without direct human intervention. Interfaces in the form of services facilitate interactions with these 'smart things' over the Internet, query and change their state and any information associated with them, taking into account security and privacy issues.

Greeves (Green Leaves), is a smart Houseplant Watering and Monitoring system that monitors and tracks environmental conditions, helping the plants thrive. The Garden Sensors gather and analyze data about changing weather and soil moisture conditions and then connects to user's Android phone with timely alerts. Also, the system includes a .Net Application which runs on a Microsoft Windows Computer which can be used to monitor the plant's conditions at user's workplace.

The system tracks humidity, temperature and soil moisture, and then uploads this information to the databases on Cloud. Greeves continuously monitors the conditions and alerts the user to the changes that require immediate action. Unlike pre-set sprinklers, the Greeves Water Valve automatically controls the existing water system based on data collected by the Garden Sensor and adapts to every change in the plant's requirements. This saves water, lowers utility bills, and the user needs never to worry about thirsty plants again.

II. Internet of Things (IoT)

The Internet of Things (IoT) describes the revolution already under way that is seeing a rising number of internet enabled devices that can network and communicate with each other and with other web-enabled gadgets. IoT refers to a state where Things (e.g. objects, environments, vehicles and clothing) will have more and more information associated with them and may have the ability to sense, communicate, network and produce new information, becoming an integral part of the Internet [21]. The basic idea is that IoT will connect objects around us (electronic, electrical, non electrical) to provide seamless communication and contextual services provided by them. Development of RFID tags, sensors, actuators, mobile phones make it possible to materialize IoT which interact and co-operate each other to make the service better and accessible anytime, from anywhere. It links the objects of the real world with the virtual world, thus enabling anytime

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connectivity for anything at any place. It refers to a world where physical objects and beings, as well as virtual data and environments, all interact with each other in the same space and time.

A. *Importance of IoT*

Before we begin with the importance of IoT, it is needed to understand the differences between the Internet and the World Wide Web (or web)—terms that are often used interchangeably. The Internet is the physical layer or network made up of switches, routers, and other equipment. Its major function is to transport information from one point to another quickly, reliably, and securely. On the other hand, the web is an application layer that operates on top of the Internet. Its primary role is to provide an interface that makes the information flowing across the Internet usable [3]. The web has gone through several distinct evolutionary stages:

First was the research phase, when the web was called the Advanced Research Projects Agency Network (ARPANET). During this time, the web was primarily used by academia for research purposes. The second phase of the web can be coined “brochureware”. Characterized by the domain name “gold rush,” this stage focused on the need for almost every company to share information on the Internet so that people could learn about products and services. The third evolution moved the web from static data to transactional information, where products and services could be bought and sold, and services could be delivered. During this phase, companies like eBay and Amazon.com exploded on the scene. This phase also will be infamously remembered as the “dot-com” boom. The fourth stage, where we are now currently, is the “social” or “experience” web, where companies like Facebook, Twitter, and Groupon have become immensely popular and profitable (a notable distinction from the third stage of the web) by allowing people to communicate, connect, and share information (text, photos, and video) about themselves with friends, family, and colleagues.

By comparison, the Internet has been on a steady path of development and improvement, but arguably hasn’t changed much. It essentially does the same thing that it was designed to do during the ARPANET era. For example, in the early days, there were several communication protocols, including AppleTalk, Token Ring, and IP. Today, the Internet is largely standardized on IP.

In this context, IoT becomes immensely important because it is the first real evolution of the Internet—a leap that will lead to revolutionary applications that have the potential to dramatically improve the way people live, learn, and work.

Humans evolve because they communicate. Once fire was discovered and shared, it didn’t need to be rediscovered, only communicated. A more modern example is the discovery of the helix structure of DNA, molecules that carry genetic information from one generation to another. The principle of sharing information and building on discoveries can best be understood by exploring how humans process. From bottom to top, the pyramid layers include data, information, knowledge, and wisdom. Data is the raw material that is processed into information. Individual data is not very useful, but volumes of it can identify trends and patterns. In the simplest sense, knowledge is information of which someone is aware. Wisdom is then born from knowledge when added with experience. While knowledge changes over time, wisdom is timeless, and it all begins with the acquisition of data.

With the development of economy and the advent of information-based society, people's requirements for living condition are continuously increasing [4]. As the planet’s population continues to increase, it becomes even more important for people to become stewards of the earth and its resources. In addition, people desire to live healthy and comfortable lives for themselves, their families, and those they care about. By combining the ability of the next evolution of the Internet (IoT) to sense, collect, transmit and distribute data on a massive scale with the way people process information, humanity will have the knowledge and wisdom it needs not only to survive, but to thrive in the coming months, years, decades, and centuries.

B. *Challenges & Barriers to IoT*

Several barriers, however, have the potential to slow the development of IoT. The three largest are the deployment of IPv6, power for sensors, and agreement on standards [5].

Deployment of IPv6: The world ran out of IPv4 addresses in February 2010. While no real impact has been seen by the general public, this situation has the potential to slow down the progress of IoT since the potentially billions of new sensors will require unique IP addresses. In addition, IPv6 makes the management of networks easier due to auto configuration capabilities and offers improved security features.

Sensor energy: For IoT to reach its full potential, sensors will need to be self-sustaining. It would be a very tedious task to change batteries in billions of devices deployed across the planet and even into space. Obviously, this isn’t possible. An effortless way is required for sensors to generate electricity from environmental elements such as vibrations, light, and airflow. In a significant breakthrough, scientists announced a commercially feasible nanogenerator- a flexible chip that uses body movements such as the pinch of a finger to generate electricity—at the 241st National Meeting & Exposition of the American Chemical Society in March 2011.

Standards: While much progress has been made in the area of standards, more is considered necessary, especially in the areas of security, privacy, architecture, and communications. IEEE is just one of the organizations working to solve these challenges by making sure that IPv6 packets can be routed across different network types. It is important to note that while barriers and challenges exist, they are not insurmountable. Given the benefits of IoT, these issues will get worked out very soon. It is just a matter of time [19].

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III. Related Work

Application development in the Internet of Things (IoT) is challenging because it involves dealing with a broad range of related issues such as lack of separation of concerns and lack of high-level of abstractions to address both the large scale and heterogeneity. Additionally, stakeholders involved in the application development have to address issues that can be attributed to different life-cycles phases when developing applications. First, the application logic has to be analyzed and then separated into a set of distributed tasks for an underlying network. Then, the tasks have to be implemented for the specific hardware. Apart from handling these issues, they have to deal with other aspects of life-cycle such as changes in application requirements and deployed devices.

Several approaches have been proposed in the closely related fields of wireless sensor network, ubiquitous and pervasive computing, and software engineering in general to address the above challenges. However, existing approaches only cover limited subsets of the above mentioned challenges when applied to the IoT. [15] proposes an integrated approach for addressing the above mentioned challenges. The main contributions are the development methodology that separates IoT application development into different concerns to provide a conceptual framework for the development of an application and the framework that implements the development methodology to support actions of stakeholders. The development framework provides a set of modeling languages to specify all development concerns and abstracts the heterogeneity related complexity.

[5] describes the essence of IoT and related issues in the current scenario. [6] and [8] elaborates the use of web of Things in smart homes and their implementations. The Internet of Things represents a dream in which the Internet extends into the real world embracing everyday objects. Physical items are no longer disconnected from the virtual world, but can be controlled remotely and can act as physical access points to Internet services. [7] reviewed recent trends and challenges on interoperability, and discuss how semantic technologies, open service frameworks and information models can support data interoperability in the design of the Future Internet, taking the IoT and Cloud Computing as reference examples of application domains. [9] presents a Cloud centric vision for worldwide implementation of Internet of Things. The key enabling technologies and application domains that are likely to drive IoT research in the near future are discussed. A Cloud implementation using Aneka, which is based on interaction of private and public Clouds is presented. The paper concludes with an IoT vision by expanding on the need for convergence of WSN, the Internet and distributed computing directed at technological research community. [10] proposes an architecture that enables objects to exchange information through the Internet to achieve nonintrusive behavior and customized services based on an open source cloud platform. To realize this goal, the information driven interactions are done not only in a peer to peer method, but also via advanced cloud services. The result is a generic platform where devices, systems and services will take part in a heterogeneous and decentralized architecture. The paper demonstrates that IoT is all about interoperability, from connected cloud computing using RFID, NFC, M2M and sensor technology to digital content and context-aware services. [11] focuses on a common approach to integrate the Internet of Things (IoT) and Cloud Computing under the name of CloudThings architecture. The authors review the state of the art for integrating Cloud Computing and the Internet of Things. An IoT-enabled smart home scenario to analyze the IoT application requirements was examined. The authors also propose the CloudThings architecture, a Cloud-based Internet of Things platform which accommodates CloudThings IaaS, PaaS, and SaaS for accelerating IoT application, development, and management. Moreover, they present the progress in developing the CloudThings architecture, followed by a conclusion. [12] reviews the literature about the integration of Cloud and IoT by starting to analyze and discuss the need for integrating them, the challenges deriving from such integration, and how these issues have been tackled in literature. Then, the application scenarios that have been presented in literature, as well as platforms -- both commercial and open source -- and projects implementing the CloudIoT paradigm are described. Finally, the open issues, main challenges and future directions in this promising field are discussed. [13] presents a flexible standalone, low cost smart home system, which is based on the Android app communicating with the micro-web server providing more than the switching functionalities. The Arduino Ethernet is used to eliminate the use of a personal computer (PC) keeping the cost of the overall system to a minimum while voice activation is incorporated for switching functionalities. Devices such as light switches, temperature sensors, humidity sensors, current sensors, intrusion detection sensors, gas sensors and sirens have been integrated in the system to demonstrate the feasibility and effectiveness of the proposed smart home system. [14] investigates and points out several problems that need to be efficiently solved for the Internet of Things to work on large scale numbers. One of the main tasks is to make devices easily discoverable. The authors propose a general cloud-based IoT architecture aimed at solving the above-described problems.

IV. Cloud Computing

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources [25] (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. The main reason for the existence of different perceptions of cloud computing is that cloud computing, unlike other technical terms, is not a new technology, but rather a new operations model that brings

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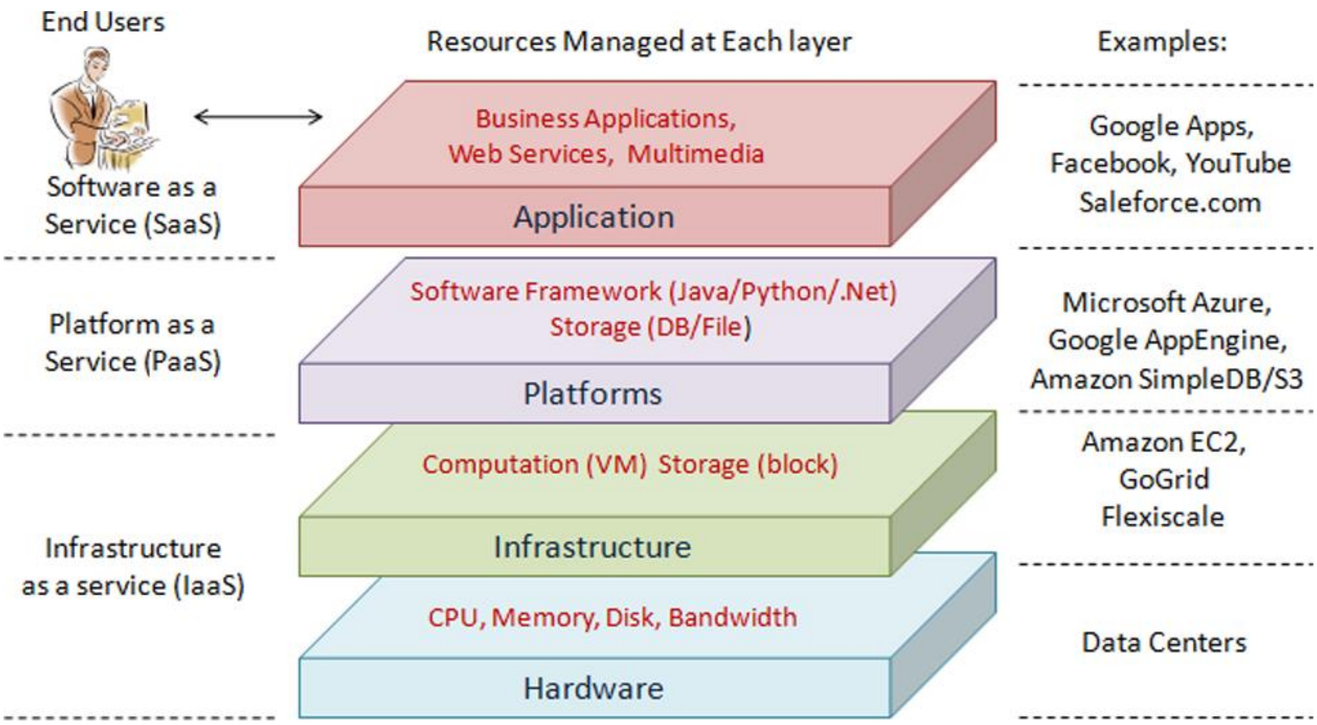

Fig. 1. Cloud computing architecture

together a set of existing technologies to run business in a different way [27]. Indeed, most of the technologies used by cloud computing, such as virtualization and utility-based pricing, are not new. Instead, cloud computing leverages these existing technologies to meet the technological and economic requirements of today's demand for information technology. Cloud computing, or in simpler shorthand just "the cloud", also focuses on maximizing the effectiveness of the shared resources [22]. Cloud provides on-demand service and storage resources to the clients. It provides access to these resources through internet and comes in handy when there is a sudden requirement of resources [1].

A. Architecture of Cloud Computing

Generally speaking, the architecture of a cloud computing environment can be divided into 4 layers: the hardware/ datacenter layer, the infrastructure layer, the platform layer and the application layer, as shown in Fig. 1.

The Hardware layer: This layer is responsible for managing the physical resources of the cloud, including physical servers, routers, switches, power and cooling systems. In practice, the hardware layer is typically implemented in datacenters [1]. A datacenter usually contains thousands of servers that are organized in racks and interconnected through switches, routers or other fabrics. Typical issues at hardware layer include hardware configuration, fault tolerance, traffic management, power and cooling resource management.

The Infrastructure layer: Also known as the virtualization layer, the infrastructure layer creates a pool of storage and computing resources by partitioning the physical resources using virtualization technologies such as VMware. The infrastructure layer is an essential component of cloud computing, since many key features, such as dynamic resource assignment, are only made available through virtualization technologies.

The Platform layer: Built on top of the infrastructure layer, the platform layer consists of operating systems and application frameworks. The purpose of the platform layer is to minimize the burden of deploying applications directly into VM containers. For example, Google App Engine operates at the platform layer to provide API support for implementing storage, database and business logic of typical web applications.

The Application layer: At the highest level of the hierarchy, the application layer consists of the actual cloud applications. Different from traditional applications, cloud applications can leverage the automatic-scaling feature to achieve better performance, availability and lower operating cost.

B. Types of Clouds

There are many issues to consider when moving an enterprise application to the cloud environment. For example, some service providers are mostly interested in lowering operation cost, while others may prefer high reliability and security. Accordingly, there are different types of clouds, each with its own benefits and drawbacks:

Public clouds: A cloud in which service providers offer their resources as services to the general public. Public clouds offer several key benefits to service providers, including no initial capital investment on infrastructure and shifting of risks to infrastructure providers. However, public clouds lack fine-grained control over data, network and

ISSN: 2278 – 7798

security settings, which hampers their effectiveness in many business scenarios.

Private clouds: Also known as internal clouds, private clouds are designed for exclusive use by a single organization. A private cloud may be built and managed by the organization or by external providers. A private cloud offers the highest degree of control over performance, reliability and security. However, they are often criticized for being similar to traditional proprietary server farms and do not provide benefits such as no up-front capital costs.

Hybrid clouds: A hybrid cloud is a combination of public and private cloud models that tries to address the limitations of each approach. In a hybrid cloud, part of the service infrastructure runs in private clouds while the remaining part runs in public clouds. Hybrid clouds offer more flexibility than both public and private clouds. Specifically, they provide tighter control and security over application data compared to public clouds, while still facilitating on-demand service expansion and contraction. On the down side, designing a hybrid cloud requires carefully determining the best split between public and private cloud components.

V. Integration of IoT & Cloud Computing

The Internet of Things (IoT) paradigm is based on intelligent and self configuring nodes (things) interconnected in a dynamic and global network infrastructure. It represents one of the most disruptive technologies, enabling ubiquitous and pervasive computing scenarios. IoT is generally characterized by real world and small things with limited storage and processing capacity, and consequential issues regarding reliability, performance, security, and privacy. On the other hand, Cloud computing has virtually unlimited capabilities in terms of storage and processing power, is a much more mature technology, and has most of the IoT issues at least partially solved. Thus, a novel IT paradigm in which Cloud and IoT are two complementary technologies merged together is expected to disrupt both current and future Internet. This new paradigm is named as CloudIoT [13].

A. Need for Integration

The two worlds of Cloud and IoT have seen an independent evolution. However, several mutual advantages deriving from their integration have been identified and are foreseen in the future. On one hand, IoT can benefit from the virtually unlimited capabilities and resources of Cloud to compensate its technological constraints (e.g., storage, processing and energy). Specifically, the Cloud can offer an effective solution to implement IoT service management and composition as well as applications that exploit the things or the data produced by them. On the other hand, the Cloud can benefit from IoT by extending its scope to deal with real world things in a more distributed and dynamic manner, and for delivering new services in a large number of real life scenarios. With the advent of the cloud technologies, the concept of IOTs can be integrated with even the basic elements having limited computing power [2]. Essentially, the Cloud acts as intermediate layer between the things and the applications, where it hides all the complexity and the functionalities necessary to implement the latter. This framework will impact future application development, where information gathering, processing, and transmission will produce new challenges to be addressed, also in a multi-cloud environment. In the following text, some of the solved issues and the advantages obtained when adopting the CloudIoT paradigm are summarized:

Storage resources: IoT involves by definition a large amount of information sources (i.e., the things), which produce a huge amount of non-structured or semi-structured data having the three characteristics typical of Big Data: volume (i.e., data size), variety (i.e., data types), and velocity (i.e., data generation frequency). Hence it implies collecting, accessing, processing, visualizing, archiving, sharing, and searching large amounts of data. Offering virtually unlimited, low-cost, and on-demand storage capacity, Cloud is the most convenient and cost effective solution to deal with data produced by IoT. This integration realizes a new convergence scenario, where new opportunities arise for data aggregation, integration, and sharing with third parties. Once into the Cloud, data can be treated in a homogeneous manner through standard APIs, can be protected by applying top-level security, and directly accessed and visualized from any place.

Computational resources: IoT devices have limited processing resources that do not allow on-site data processing. Data collected is usually transmitted to more powerful nodes where aggregation and processing is possible, but scalability is challenging to achieve without a proper infrastructure. The unlimited processing capabilities of Cloud and its on-demand model allow IoT processing needs to be properly satisfied and enable analyses of unprecedented complexity [1] [2]. Data-driven decision making and prediction algorithms would be possible at low cost and would provide increasing revenues and reduced risks. Other perspectives would be to perform real-time processing (on-the-fly) to implement scalable, real-time, collaborative, sensor-centric applications to manage complex events and to implement task offloading for energy saving.

VI. Proposed System

The system is generally meant for the plant lovers who are very busy in their jobs or day- to- day lives. Sometimes, people forget to take care of their plants. This leads to improper growth of the plant which ultimately upsets the plant owners. After the installation of the system, the users can actually forget about watering the plant on regular basis as the system takes care of this tedious job for them.

The system tracks humidity, temperature and soil moisture, and then uploads this information to the databases on Cloud. Soil Moisture Sensor can be used to detect the moisture of soil or judge if there is water around the sensor [4]. Greeves (Green Leaves) continuously monitors the conditions and alerts the user to the changes that require immediate action. Unlike pre-set sprinklers, the Greeves Water Valve automatically controls the existing water

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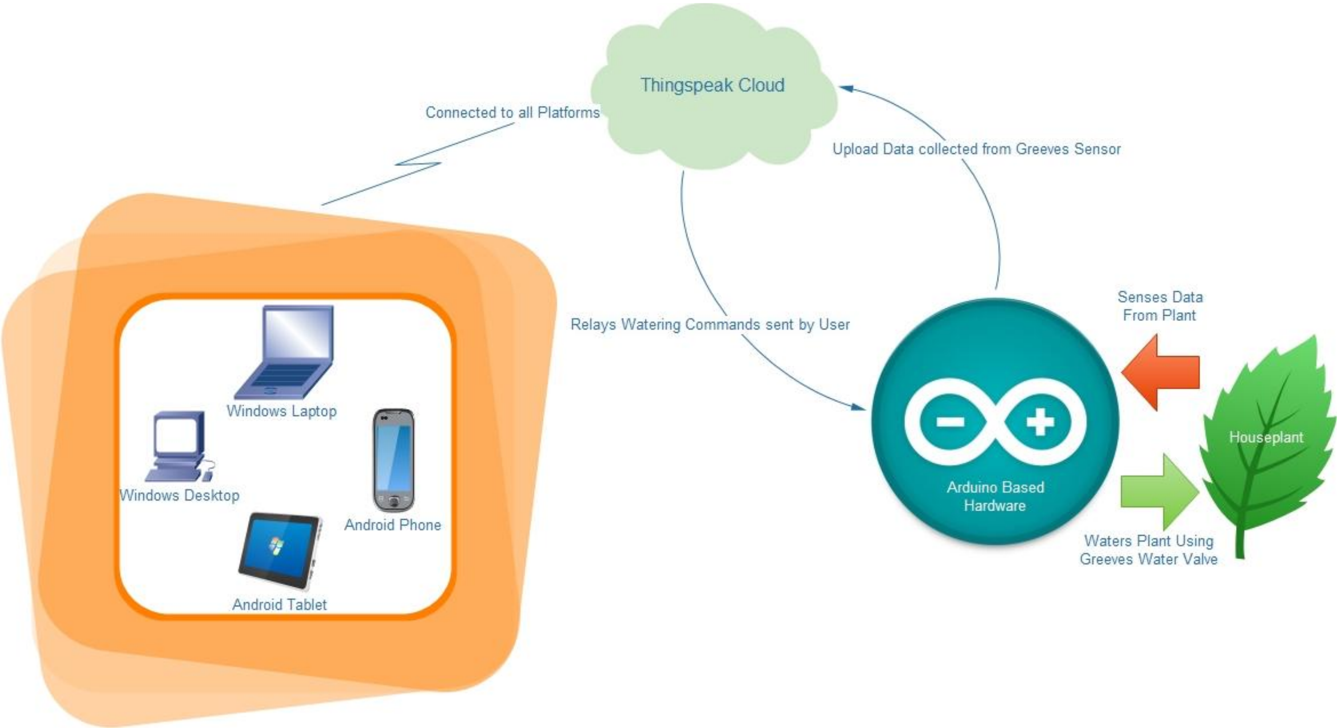

Fig. 2. Proposed System Architecture for Greeves

system based on data collected by the Garden Sensor and adapts to every change in the plant's requirements. This saves water, lowers utility bills, and the user needs never to worry about thirsty plants again.

The user can also use the Greeves app to manually control the Water Valve, allowing the user to water plants from anywhere. That means the user can actually pour his/her love on the plants by watering it any time and from anywhere. The Greeves Water Valve can simply be attached to a hose, making it the simplest watering control device yet. It'll also turn on or off based on the sensor's readings, giving plants the precise amount of moisture that they need. The system displays different types of charts and graphs plotted to check on the plant's details. Also, the system uses an open-source cloud database to minimize the costs on the issue of storing large amounts of data. The system gathers and relays sensor data every 10- 15 seconds. The data is then stored and finally sent to the Android app on the phone and Windows Application on the desktop computer. Also, the system checks regularly for Plant Watering commands from the user which can be directed from either the Android app or the Windows application.

Also, if somehow the water tank is empty, the system informs the user through Twitter and tweets the warning message which is relayed to the user having a twitter app on phone. In this way, the system always tries to inform the user about the plant's moisture conditions in such cases of emergencies. It integrates Android, Windows, Arduino and Thingspeak Cloud together to work in tandem making the system achieve its set goals. The system aims to make gardening, an enjoyable experience for everyone.

Many Kickstarter projects are based on the issue of plant watering and monitoring but most of them are under development and are too costly to be bought by Indian users. Kickstarter is the world's largest funding platform for creative projects. The system is developed at a very low implementation and development cost and assures to be successful in comparison to the other systems in the market which are yet to release their final product. We have used Android, Arduino and Thingspeak Cloud. All of these platforms are open- source and free to use. This reduces most of the implementation cost on the system which is the primary aim of the project.

The architecture as shown in Fig. 2 involves Arduino Based Hardware fitted with soil moisture sensor and temperature sensor to interact with the Houseplant. The recorded soil moisture sensor values are received by the Arduino microcontroller which is pre-programmed to relay the data to Cloud. The cloud stores the values discarding noisy data. Here, we have used Thingspeak API to store data to the Thingspeak Cloud. Cloud is connected with the major platforms such as Microsoft Windows and Android. The apps designed on these platforms are built to retrieve the moisture, temperature and humidity data. The data is visualized using Charts, Graphs and numerical values. These applications are designed to display real-time data. The refresh gap is set to 5 seconds.

The architecture of the system is designed as not only to retrieve data from the Houseplant but also to give commands to the Arduino Hardware to water the Houseplant. In this way, the Cloud and the front-end applications are 2- way connected.

ISSN: 2278 – 7798

VII. Experimental Results

The results generated are given below and visualized using charts. The charts show the moisture, temperature and humidity levels of a houseplant outside a room. Different types of charts are generated by the system used to monitor the plant details such as Line chart, Column chart, Bar chart and Spline chart. These results were generated after the successful implementation and deployment of the system. While analyzing the graph closely, one would identify the sudden rise in moisture levels at a very high rate just before the last few readings. The system was pre-programmed to react when the moisture levels reach below a certain level. In this scenario, it was considered that a moisture level of 440 points is low which means that the system should trigger some action when the readings are low. Here, the system automatically pours out water from the Greeves Water Valve in a way that the moisture readings are high again which is clearly displayed in the graph generated by the system at the front-end. Generally, soil moisture is the water that is held in the spaces between soil particles. We were mostly concerned with the surface soil moisture that is the water present in the upper 10 cm of soil [21], whereas root zone soil moisture is the water that is available to plants, which is generally considered to be in the upper 200 cm of soil. One of the aims of the work was to develop the system in an atmosphere which should be managed as well as cost-effective primarily. Most of the development cost was reduced because of the use of open- source technologies such as Android and Arduino. The DHT11 sensors used to read the temperature and humidity readings were also cheap [18] [26] which helped reducing the expenditures for developing the syste. Also, Thingspeak cloud was used which is open-source and provides free service for data storage and retrieval[24].

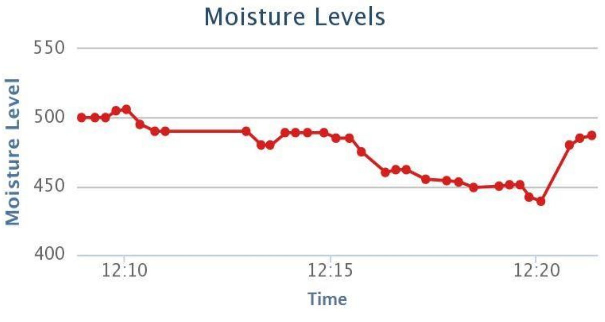

Fig. 3. Moisture Levels (Line Chart)

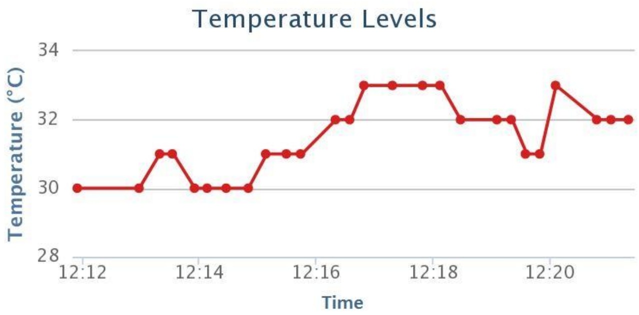

Fig. 4. Temperature Levels (Line Chart)

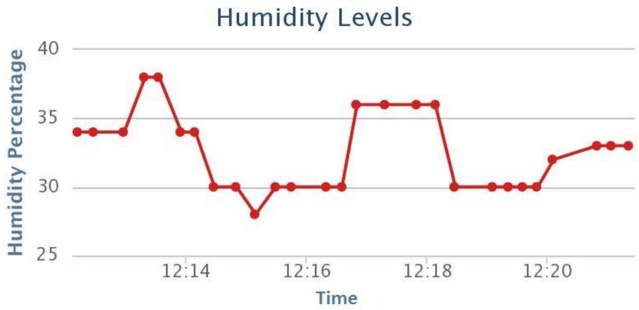

Fig. 5. Humidity Levels (Line Chart)

It was crucial to reduce the implementation cost or the expenditure on the devices used practically. One of the many ways was to use cost- effective sensors which may not affect the system efficiency at all by any means. There are many sensors available for sensing the temperature in the market. Some of them are extremely fast, reactive, precise and expensive too. The temperature sensor used in the system does not require any quick and reactive behavior to temperature changes because the system is to be deployed in rooms or outside a room. The DHT11 sensor used takes a bit of time to react to a sudden change in temperature. The temperature at these places generally does not change instantly which means that this sensor is appropriate for such scenarios as explained above. This explains that the sensor is not too expensive and also lives up to the claimed accuracy. It is also to be noted from the comparison table that the operating humidity range of the DHT11 sensor used in the system 20- 90% which implies that system would not be able to relay the precise humidity values outside such range. The comparison table of different temperature and humidity sensors is detailed in Table I.

VIII. Summary and Conclusions

Greeves, a smart houseplant watering and monitoring system eases the tedious job of gardening in time of rush for plant lovers. It monitors plant levels and informs the user with the details on their smartphones and desktops. It is also able to overcome many of the issues faced in the existing watering systems. This system helps to reduce the amount of water wasted during improper bucket watering. It proves to

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be an efficient system to reduce the issue of overwatering the plants which leads to diseases and make plants more prone to pests [17], [23].

Table I. Comparison of different temperature and humidity sensors in the market [16]

Manufacturers' Specification			
	AM2302 /DHT22	***DHT11***	***SHT71***
Range	0-100%	20-90%	0-100%
Absolute accuracy	±2%	±5%	±3%
Repeatability	±1%	±1%	±0.1%
Long term stability	±0.5% per year	±1% per year	<0.5% per year
Typical street price	US$ 4-10	US$ 1-5	US$ 30-50

The system is successfully developed and is efficiently working. The results were generated and analyzed visually with the help of charts and different types of graphs. Results generated are correct and up to the mark.

The idea of an automated system to monitor houseplants and interact with them using the integration of different technologies together was conceptualized and implemented in a well managed and objective environment. The main challenge was to reduce the implementation cost of the system which was insightfully analyzed and worked upon. More amount of free and open- sources technologies were used during development which helped achieving the set goals. The system proves out to be cost- effective as compared to other products in the market and the ones which are yet to be released.

The development was done keeping in mind such that there is no restraint on the platforms to retrieve data. This means that whichever new technology arises, this system will be able to adapt to it because the underlying data gathering and retrieval process is based on web. The system architecture assures no limitations and boundaries on the front- end of the system. Furthermore, the data collected by the system on cloud can be easily retrieved and stored in a local SQL Server. Using available data mining algorithms, one would easily find out the time intervals of some specific plant's water requirements in a particular climate condition. With the help of this information, the microcontroller could be put to sleep during the intervals where the plant generally does not require any attention.

Also, this work could be expanded to a very large extent in agriculture. The system could be implemented with modifications in agricultural fields with multiple moisture sensors forming a wireless sensor network (WSN). Different plants and crops require different amounts of water. Also, the ground level is not the same everywhere which means that the water could be carried by the surface unevenly. These sensors could interact with each other to assure that irrigation is carried out at the right places in the field where the moisture levels are very low. This can improve the precision of the system and would prevent damages caused due to overwatering.

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Dr. W. Jeberson is working as an Associate Professor and Head of the Department of Computer Science and Information Technology , Sam Higginbottom Institute of Agriculture, Technology and Sciences. He has a vast experience of more than 8 years in teaching and 3 years in industry. He has attended many Internation Conferences and has immense knowledge in the field of Computer Science. His area of specialization are Software Engineering and e- governance.

Er. Anchit S. Dhar is presently employed as an Assitant Professor in the Department of Computer Science & Information Technology, Sam Higginbottom Institute of Agriculture, Technology and Sciences. His areas of interest are Data Structures, Algorithm Design and Analysis and Database Programming.

Er. Vineet Biswal is post graduate student pursuing M.Tech in Computer Science and Engineering from Sam Higginbottom Institute of Agricultural, Technology and Sciences in the Department of Computer Science and Information Technology. His areas of interest are Operating Systems, Data Structures and Advanced Programming Languages.

Er. Hari Mohan Singh is employed as an Assistant Professor in the Deparment of Computer Science & Information Technology, Sam Higginbottom Institute of Agriculture, Technology and Sciences. His research areas other than IoT are Network Survivability, Mobile Computing and Parallel Algorithms.

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