



Investigating the factors affecting the development of the Internet of Things framework in the smart city from the perspective of energy consumption optimization

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Abstract

The Internet of Things (IoT) is a novel concept in the field of information and communication technology, and in recent years, the implementation of IoT in smart city environments has garnered significant attention from research communities and end-users. The IoT refers to a network where every physical object is identified by a unique identifier and interconnected with other objects.

With the rise in energy tariffs, the discussion surrounding energy consumption and its associated costs in cities has taken on new dimensions. Since the sensor nodes in IoT networks are typically powered by batteries, the critical issue that must be investigated is how to reduce the energy consumption of these nodes to extend the overall lifetime of the network to an acceptable level.

The aim of the current research is to provide an optimal framework for the IoT and then simulate the IoT infrastructure using the Cooja IoT simulator in order to analyze the energy consumption data and propose suitable solutions. The primary application of this simulator is for networked devices with limited memory and energy resources, particularly wireless IoT equipment.

This research investigates various methods and tools that can potentially reduce energy consumption in these IoT networks.

Keywords: Internet of things, smart city, energy efficiency

Introduction

The emergence of the Internet of Things (IoT) has had a significant impact on people's lives, making various aspects more convenient and efficient. In recent years, the IoT has found its way into numerous fields, becoming increasingly prominent due to advancements in communication technologies, such as radio frequency identification (RFID), near-field communication (NFC) devices, and embedded sensor nodes.

The IoT depicts a future where physical objects and devices around us, including sensors, RFID tags, location equipment, and mobile devices, will seamlessly integrate with the Internet. These interconnected objects and devices will enable enhanced connectivity, collaboration, and communication, providing social, personal, and environmental data to achieve common goals.

The integration of IoT technologies within smart city infrastructures empowers citizens to gain valuable insights about their surroundings and actively participate in data collection through mobile devices. This integration also makes data more accessible and queryable, leading to a more homogeneous access to the available data sources in a smart city.

IoT is a novel concept in the realm of technology and communication, where any entity, be it human, animal, or object, can transmit data through communication networks, including the Internet or intranets. This technology allows for the transformation of ordinary objects into intelligent, interconnected devices that can be remotely controlled.

According to Cisco's predictions, by the year 2020, the number of connected devices is expected to reach 50 billion, creating a dense IoT environment. These IoT devices span a wide range, including smart gas meters, smart watches, air quality monitoring systems, and smart control systems that are integral to smart rescue operations. Various sensors, such as temperature, accelerometer, pressure, and humidity sensors, play a crucial role in enabling the IoT ecosystem.

The widespread adoption and implementation of the Internet of Things hold the potential to revolutionize current mobile and fixed network infrastructures, establishing it as an essential component of the future Internet. As the IoT continues to evolve, it promises to bring about remarkable advancements in people's lives and the way they interact with their surroundings. According to the definition of the International Telecommunication Union, ITU (2016), the Internet of Things is a global infrastructure for the information society that enables advanced services by connecting physical and virtual objects based on existing and evolving information and communication technologies (Dehuy and Sahoo, 2016).

The Internet of Things is a heterogeneous network because it consists of independently developed networks and equipment with different purposes. As a result, energy consumption in the Internet of Things is a challenging issue. The methods presented so far to reduce energy consumption have generally not considered the characteristics of the Internet of Things, including the nature of interdependence between different objects, the limited data game, and the large number of IoT nodes (Theodorou and Lefteris, 2017).

The Internet of Things consists of extensive networks and a large number of devices that interact with each other. Therefore, in order for several nodes to work together with high performance and low energy consumption, it is necessary to provide a method that considers all objects as a single set. (Kurt et al., 2016).

The Internet of Things (IoT) is created by a large number of small and low-cost sensor nodes that are organized in a self-organized manner. After collecting information from the environment, the sensors send the data to the sink through wireless communication. The main task of the IoT is to monitor related issues in the field of network coverage and transfer the monitoring results from the sink to the supervisor. After gathering information in the sink, the results are sent to the monitoring center through a high-speed Internet line (Wang et al., 2018).

Monitoring can be done using artificial intelligence algorithms, machine learning, and data mining to extract useful information from the collected data and provide it to supervisors and managers through mobile applications (Yessemayev et al., 2018).

With the expected growth in the world's population, the demand for energy will continuously increase. The current energy grids were built decades ago, and despite being updated regularly, their ability to meet future demands is uncertain. The available reserves of fossil fuels are limited and emit harmful substances with unavoidable environmental and social impacts. The concept of the IoT, combined with smart metering, has the potential to transform homes, offices, and other environments into energy-conscious spaces (Risteska Stojkoska & Trivodalie, 2017).

The IoT leads to increased visibility and awareness of energy consumption with the help of smart sensors and smart meters in devices. Real-time data from energy consumption can then be easily collected and analyzed to guide energy

improvement decisions (Shouf & Miragliotta, 2015). Energy efficiency is one of the critical issues for the mass deployment of wireless sensor networks and IoT applications (Nguyen, Khan et al., 2017).

Considering the increasing need for energy resources and the reduction of fossil fuel resources, the necessity of keeping the environment healthy, reducing air pollution, and the limitations of electricity and fuel supply, consumption management is a crucial and strategic topic for achieving excellence and economic development. Recent advancements in intelligent systems have led to significant progress in the field of monitoring and managing energy consumption, increasing its functional efficiency.

To fully exploit the potential of the IoT, a comprehensive understanding of the underlying technologies and the IoT architecture is essential. This research aims to examine the effective factors in the development of an IoT framework in a smart city, with a focus on optimizing energy consumption, and provide an effective solution for the improvement of established IoT frameworks.

Methodology

The provided text is generally grammatically correct, though there are a few areas that could be improved for better clarity and flow. Here's a revised version with some minor edits:

In this research, the library method was used to review articles published in scientific journals and internet-based scientific resources and databases, enabling the researcher to gather the required information. This research is applied in nature, with a descriptive approach to data usage. The target population includes creators, developers, and users of Internet of Things (IoT) systems and frameworks.

Given that the field of IoT is still evolving and presents numerous challenges, this research focuses on the issues related to the development of IoT frameworks within the country. The research scope includes smart health, smart citizens, and smart transportation, with a specific focus on the field of smart energy. The IoT currently has a significant influence on energy management, and this research aims to provide an effective solution in smart energy to create a suitable platform for the control and optimization of energy within the IoT framework. In this research, a combined model based on existing conceptual models suitable for the research location is used, which has not been implemented in the country before.

This project aims to increase the success of IoT-related projects by identifying effective factors for the development of IoT frameworks and, considering successful global examples, proposing a suitable framework for the country. The IoT development criteria outlined in this research will be valuable for students and researchers investigating similar topics.

Findings

IoT sensor devices typically have limited memory, CPU, and power resources. Energy consumption and limited device resources are critical issues for IoT systems with limited energy sources. This function measures the processor's usage time. This function has 94% accuracy compared to measurements by real instruments. Table 1 shows the data provided by this function in the 100-second simulation of the protocol, with the client mote's energy consumption calculated every 10 seconds

<i>CPU</i>	<i>RX</i>	<i>TX</i>	<i>LPM</i>	<i>sum</i>
0.053608887	1.644598389	0.359862671	0.003120025	2.061189971
0.053808289	1.782810059	0.360021973	0.00311938	2.1997597
0.048055847	1.614821777	0.306177979	0.003138213	1.972193816
0.044137299	1.469208984	0.270175781	0.003151566	1.786673631
0.049623871	1.657335205	0.324656982	0.003133248	2.034749306
0.044892609	1.446833496	0.287698975	0.003149653	1.782574732
0.046131317	1.553891602	0.288017578	0.003144446	1.891184943
0.04487146	1.464217529	0.270016479	0.003150459	1.782255927
0.050784027	1.621534424	0.337241821	0.003128202	2.012688474
0.047013519	1.534958496	0.288017578	0.003141898	1.873131492

Table 1: Coap protocol simulation data for sky node

After extracting the data in the previous simulation conditions, mote 21 was used instead of sky mote, whose hardware features include the following and are different from sky node:

- Equipped with a low-power MSP430F2617 microcontroller
- ۱۶bit RISC CPU
- ۱۶MHz Clock Speed KB RAM
- ۹۲KB Flash Memory
- Compliant with IEEE 802.15.4
- Speed of 2.4 GHz with a data rate of 250 kbps
- Maximum efficiency with low energy cost
- A digital programmable accelerometer (ADXL345)
- A digital temperature sensor (TMP102)
- The possibility of supplying energy by connecting to a 3.3V battery or from the 5V u-USB port

<i>CPU</i>	<i>RX</i>	<i>TX</i>	<i>LPM</i>	<i>sum</i>
0.02968369	0.9172229	0.16200989	0.00319969	1.11211617
0.03219434	1.01567505	0.17985168	0.00319131	1.23091238
0.03203421	1.03546875	0.18017029	0.0031918	1.25086505

0.03191638	0.9855542	0.18001099	0.00319222	1.20067379
0.03321249	1.02032227	0.17443542	0.00318788	1.23115807
0.03218829	1.04235352	0.18001099	0.0031913	1.25774409
0.02980151	0.90534668	0.16200989	0.00319934	1.10035742
0.03209464	1.01842896	0.18001099	0.00319167	1.23372624
0.0321611	1.05457397	0.18001099	0.00319146	1.26993752
0.03185898	1.02428101	0.18001099	0.00319247	1.23934344
				1.212683417

Table 2: Coap protocol simulation data for z1 node

Examining the data shows that energy consumption varies based on the device and sensor used. The sky-type node consumes slightly more energy, but the difference is negligible. However, as the number of nodes increases, this small difference can lead to substantial energy savings. Comparing two different types of motes reveals that increasing the RAM size leads to higher energy consumption. Additionally, the simulation results indicate that higher processor power and speed result in faster calculations and reduced energy waste, ultimately optimizing the network's energy consumption.

Conclusion

The creation of massive data, efficient computer networks, and cost-effective sensors have presented countless opportunities for businesses to optimize their operations and enter new markets, such as the Internet of Things (IoT). IoT is one of the new opportunities that businesses can leverage to make significant changes to their IT infrastructure and improve their market positioning.

Given the ever-increasing growth of IoT, there is a strong need for a comprehensive framework that addresses the needs of pioneering companies in this field. In an IoT system, data is generated by various devices and sensors, processed, and sent to different destinations for analysis based on the requirements and nature of the applications.

The purpose of this research is to investigate IoT with a specific focus on energy consumption in different aspects of a smart city. To achieve an optimal framework that controls and significantly reduces energy costs, the IoT architecture is presented in a simplified manner. This architecture consists of three layers: sensors, network, and application. Each layer must address specific challenges to help control and optimize energy consumption in different parts of the smart city, such as transportation, smart homes and buildings, smart lighting, and waste management.

Additionally, IoT systems raise important questions regarding security and privacy. This research not only presents the framework but also introduces key security solutions and challenges across the different layers.

Creating a smart city is not only an expensive and complex project, but current technologies have become user-friendly, allowing any consumer to easily provide the necessary equipment. Furthermore, the cost of IoT equipment has become much more affordable compared to the past.



The purpose of energy management is to reduce and rationalize energy consumption in an economically justified manner, without negatively impacting well-being and comfort. The energy required by the world is consumed in sectors such as transportation, residential, commercial, and services.

Energy data collection infrastructures play a significant role in the development of the IoT framework from the perspective of optimizing energy consumption. The research has identified several infrastructures, such as smart meters, water and gas sensors, temperature and humidity sensors, and mobile device sensors, as the main components for collecting energy data. Communication protocols, including Low-power Wi-Fi, Zigbee, RPL, IEEE 802.15.4, 6LWAN, MQTT, and CoAP, have been evaluated through simulations in Cooja Contiki to assess their energy consumption.

Data management and storage systems also have a significant effect on the development of the IoT framework from the energy consumption optimization perspective. The research explored cloud processing, the use of NoSQL databases like MongoDB, and the optimization of data centers to provide a more comprehensive framework development.

The user interface and applications have a positive and significant effect on the development of the IoT framework from the energy efficiency perspective. The research identified cases in the smart city where energy control has a significant impact, including transportation, smart homes and automation, smart lighting, smart streets and roads, and smart offices. Based on the findings, a framework was presented to address the needs of different parts of the smart city.



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