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A cost-effective viable strategy for gradually transitioning Egypt's cities into truly IOT-enabled smart cities

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Abstract

A smart city is a city that uses information and communication technologies (ICT), smart sensors, actuators and video cameras to better support and optimize the delivery of urban services and to address challenges within city communities. A smart city collects and analyzes data from smart IoT sensors (IoT devices/nodes) and video cameras. The data collected by the sensor nodes can be used to develop applications and systems that benefit the city and the community.

Smart city industry is projected to be a $400 billion market by 2021, with 600 cities around the globe expected to generate 60% of the world's GDP by 2025, according to McKinsey research. Many cities have adopted at least one smart city project. However, the majority of cities around the globe are not yet smart cities. The key hurdle is securing the huge fund needed to start a smart city project, and ensuring that there are sufficient resources to sustain the project over time.

Because implementing new smart city infrastructure is a large and complex financial undertaking that poses a financial hurdle, specifically, for most of the under-developed countries, a viable and cost-effective strategy is needed to tackle this problem and conquer the digital divide. Building upon and leveraging existing infrastructure is the key to address this problem. This minimizes the cost of technology upgrades and allows for an easier integration process. In addition, leveraging existing infrastructure can give cities a better and quicker return on investment.

The main objective of this work is to devise an innovative research and development initiative, which builds upon and leverages ongoing global deployment of smart city and outdoor lighting infrastructures trend, to explore the potential and assess the feasibility of gradually transitioning existing Egypt's cities infrastructure into truly IoT-enabled smart cities. Specifically, we propose and develop an innovative cost-effective, future-proof, scalable and modular end-to-end device-to-cloud connected outdoor Lighting network infrastructure solution that is based on P2P 4G LTE cellular technology to provide the direct connectivity between lighting poles (IoT devices) and the cloud.

The proposed intelligent Lighting solution includes three key building blocks: 1) light pole-mounted smart control nodes; 2) cloud-based smart city software solution (NetServ) to remotely monitor, manage, and control the entire lighting infrastructure; and 3) P2P 4G LTE cellular network. In the proposed architecture, smart streetlights serve as the framework for a high- bandwidth, low-latency wireless sensor network, capable of transporting large amounts of data in real-time, while concurrently supporting deployment of a wide range of smart city services.

Keywords: *Smart cities; IOT; Cloud internet.*

1. Background

A smart city is a city that uses information and communication technologies (ICT), smart sensors, actuators and video cameras —connected via an intelligent network— to better support and optimize the delivery of urban services and to address challenges within city communities. These challenges may include traffic, parking, transportation, street lighting, water and waste management, safety and security, as well as the delivery of smart education and healthcare. A smart city collects and analyzes data from smart IoT sensors (IoT devices/nodes) and video cameras. The data collected by the sensor nodes can be used to develop applications and systems that benefit the city and the community. In essence, these intelligent sensors, can see, hear and feel the heartbeat of a city.

Smart city industry is projected to be a $400 billion market by 2021, with 600 cities around the globe expected to generate 60% of the world's GDP by 2025, according to McKinsey research. Many cities have adopted at least one smart city project. However, the majority of cities around the globe are not yet smart cities. The key hurdle is securing the huge fund needed to start a smart city project, and ensuring that there are sufficient resources to sustain the project over time. This will lead to a huge digital divide between the cities that can afford building new smart city infrastructure, compared to cities that can't afford such a large financial undertaking.

2. Motivations

Because implementing new smart city infrastructure is a large and complex financial undertaking that poses a financial hurdle, specifically, for most of the under-developed countries, a viable and cost-effective strategy is needed to tackle this problem and conquer the digital divide. Building upon and leveraging existing infrastructure is the key to address this problem. This minimizes the cost of technology upgrades and allows for an easier integration process. In addition, leveraging existing infrastructure can give cities a better and quicker return on investment. Existing public streetlights infrastructures are the most suitable current structures and technologies that can be upgraded to create a smart city. Specifically, smart lighting can provide cities a point of entry into achieving and creating broader smart cities infrastructures [1-4]. While most smart city applications remain at the pilot level, there is a consensus among all stakeholders that smart street lighting is a critical first step to open up these opportunities.

The first step for this transition to take place is to replace legacy streetlights with low-power Light Emitting Diodes (LEDs). LED streetlights offer longer lifetimes, lower energy consumption, and reduced maintenance expenses when compared with legacy streetlight technologies. Costs for LEDs have now mostly bottomed out, and the business case is clear. LEDs will be the dominant technology for future street lighting, and savings from LEDs will help drive additional applications. By replacing traditional sodium lamps with energy efficient LED lamps, in addition to providing a brighter street environment, running costs can be reduced by 60% [1-2].

The second step is to convert the LED light into a smart LED streetlight - or more economically, instead of installing just an LED, we can install directly in the first step a smart LED that could do much more. A smart LED has sensors embedded into it and connectivity to the cloud (Internet) [3]. It is also inexpensive to add an HD camera to a smart LED streetlight. For instance, if the new LED-based street lamps are connected to a mobile network, they can be controlled remotely as an Internet of Things (IoT) device. This connectivity enables the lights to be remotely monitored and controlled.

Under this scenario, city officials can start collecting data that cities never had before and with this data they can start to build smart city applications. City officials can now download one or more app(s) that help address the above mentioned challenges within city community - similar to the typical process of downloading an app on Android device or iPhone [3]. Integrating LED lights with intelligent controls, networking and computing capabilities can provide a further 30% in savings [4].

Smart connected LED streetlights can support a wide range of sensors and city services using the power and communications connections available on each light pole. Public lighting represents one of the finest powered grids – spread across towns and cities throughout the globe. As light poles are located throughout a city, they are the ideal spots for a wide array of sensors. Streetlights sit at a unique elevation in the city at 20-30 feet so it is natural to install HD cameras [3]. Sensors are important to the functioning of a smart city. They offer a cost effective way of creating a citywide IoT sensor network that enables the deployment of current and future smart city services. Each streetlight is then turned into sensor-equipped, smart node capable of capturing and transmitting/ receiving real-time data (digitally controllable nodes).
For instance, an environmental sensor, a security camera, an electric vehicle (EV) charger or a traffic counter can easily be mounted on a street pole. As such, IoT-enabled connected outdoor lighting networks can support a wide range of current and future smart city applications and services such as Video Surveillance for public safety, Intersection Safety Analytics (pedestrian safety), Traffic Management, Traffic Light Controls, digital signage systems, EV charging, public Wi-Fi and much more. Thus, smart street lighting infrastructures are the first critical step towards viable implementation of the envisioned IoT-enabled future smart cities.
Once IoT-enabled connected street lighting system is deployed, it can serve as the foundation for future smart city infrastructure. LED and smart streetlights are expected to reach 85% and 24% of the total streetlight market, respectively, by 2028. This will total a $50.4 billion market opportunity over the next decade [1]. Streetlights are now viewed as a critical asset to unlocking billions of dollars in smart city potential. Previously viewed as a major cost – up to 40% of a city's energy budget – streetlights are now viewed as a revenue opportunity [1].

3. Proposed Work

The main ***objective of this work*** is to develop state-of-the-art education and research initiative, which builds upon and leverage ongoing global deployment trend of smart cities and outdoor lighting infrastructures, to motivate and enable Egyptian government and city officials to gradually transition existing cities infrastructure into truly IoT-enabled smart cities. In order to achieve our vision, two key educational-research components will be concurrently developed: (1) An inclusive integrated education and research program that enables the preparation of a new generation of undergraduate/ graduate students with the breadth of training and experience required to guide the evolution of IoT-based smart city applications with particular emphasis on the civil national critical infrastructures including smart energy, smart power grid, intelligent transportations, smart water and e-healthcare.

The student's thesis (Master or Ph D), which will be selected based on the broad research theme presented here, will be jointly supervised by both faculty from Egypt and the USA. We believe that such training must take place in the academic realm, as industry research efforts have become increasingly dispersed and proprietary in nature. However, industrial participation is also a must, since this complex problem cannot be effectively solved by either alone. (2) An innovative cost-effective, future-proof, scalable and modular end-to-end device-to-cloud connected outdoor Lighting network infrastructure solution that is based on P2P 4G LTE cellular technology to provide the direct connectivity between lighting poles (IoT devices) and the cloud. In this architecture, smart streetlights serve as the framework for a high- bandwidth, low-latency wireless sensor network, capable of transporting large amounts of data in real-time, while concurrently supporting deployment of a wide range of smart city services and applications.

Because smart civil critical infrastructures (CIs), specifically, utilities (electric and water) and transportation systems are the foundation for building a truly smart city, building smart cities across the nation practically means transforming the nation's civil CI systems into smart CIs. Smart and resilient CIs including transportation, power, energy, water and telecommunication systems are vital for maintaining the national security and economic competitiveness of the nation. Due to the growing reliance on ICT, these CI systems have become increasingly interconnected and interdependent. Dependent and interdependent relationships among CI systems may provide some benefits during normal operation, but they may also pose significant threats during major disruptive events. For instance, because of interdependencies, some system failures can also trigger significant cascading failures and performance impacts on other CI systems.

The global community is well aware of utilities and transportation challenges and interdependencies, but has so far addressed them in isolation. Currently, transportation and utility sectors are developed, managed, and operated independently of one another. The rapid penetration of electric vehicles in the market, which will bring more advantages and challenges, is further creating the potential for increasing the interdependencies between transportation and utility sectors. Despite the research efforts and activities in the literature that have targeted identifying and modelling the interdependencies between transportation and utility sectors, we are still struggling to fully and clearly understand these complex systems.

In the proposed architecture, since smart LED light node houses several smart IoT sensors that may support different smart CI system applications, collecting and analysing the data from these IoT sensors (using artificial intelligence and predictive analytics) can enable us to capture real-time dynamic interdependencies between these CI systems. This can also enable real-time integration and optimization of these different CI IoT applications. This represents a first critical step en route to the ultimate vision of fully integrating real-time operation of these CI systems during both normal and emergency situations.

Our ultimate motivations and objective is to voluntarily help Egypt to catch up and synchronize with the ongoing IoT-based technological revolution around the globe and to ensure that it does not fall behind.

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