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Public street lighting remote operation and supervision system

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ABSTRACT

Public street lighting system consists of devices distributed in points of light and a supervision and control application. The system architecture is modular and expandable. In developing the work the C# language is adopted to develop the operation and monitoring via standard CyberOPC and XML file types are applied to the device description and definition of the network topology. This paper describes the validation proposed and the results obtained attests that this applied methodology is feasible and can be applied to other public lighting systems.

1. Introduction

This work is part of the project that analyzes the development of technologies for street lighting system, which is a wireless sensor network system that monitors and controls electrical variables. The system consists of devices attached to lighting points, which are interconnected via a network, and software tools for monitor and control. Moreover, the low levels of Wireless Sensor Networks (WSN) used refer to the IEEE 802.15.4 standard operating in mesh topology, through multi-hop communication based on low-range communication.

The main contribution from this paper is proposing a developing methodology and architecture for Public Street Lighting Remote Operation and Supervision System intended for sensor wireless urban networks [1]. The motivation is the search for a way to architecture recent and advanced features related to standard services and software components.

The next section describes the proposed public lighting system, as well as the specified requirements. Section 3 presents the requirements for public lighting system operation. Section 4 introduces the proposed system and details its architecture. Section 5 presents the results as well as the proposed evaluation strategies and, finally, the last section draws the conclusions.

2. Requirements for public lighting systems

The proposed public lighting system consists of an urban network that, according to the document RFC 5548 [1] — Routing Requirements for Urban Low-Power and Lossy Networks, is defined as: "Sensing and actuating nodes placed outdoors in urban environments so as to improve people's living conditions as well as to monitor compliance with increasingly strict environmental laws. These field nodes are expected to measure and report a wide gamut of data (for example, the data required by applications that perform smart-metering or that monitor meteorological, pollution, and allergy conditions). The majority of these nodes are expected to communicate wirelessly over a variety of links such as IEEE 802.15.4, low-power IEEE 802.11, or IEEE 802.15.1 (Bluetooth), which given the limited radio range and the large number of nodes requires the use of suitable routing protocols".

The recent document proposed by IETF [1], which describes requirements for routing on urban networks, also affirms that these networks must attend convergent traffic, where one node (usually a gateway or sink) receives messages from several low frequency meters (a maximum of one measurement per hour, and a minimum of one measurement per day). The number of nodes must be in the order of 10^2 to 10^7, distributed in areas varying from hundreds of meters to one square kilometer, considering that nodes are commissioned in groups, and the battery shelf life is usually in the order of 10 to 15 years. The frequency band must be ISM (Industrial, Scientific and Medical), and the nodes will probably have from 5 to 10 immediate neighbors to communicate. The routing protocol must enable the network to be autonomous and organize itself, requiring a minimum energetic cost for maintenance functions. The protocol must also ensure that any diagnostic or failure

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information from the nodes is communicated without interfering on the network operational mode, respecting the time limits. Specifically to public lighting system, according Brazilian Energy concessionaire, each node is positioned to the distance of 30 m. The number of neighbors can vary from 3 to 34 for public street lighting.

In the literature, as in the solutions found in the industry, it is seen that the existence of a standard on the functionalities needed to manage the public street lighting system. In general, Denardin et al. [2] affirm that a public street lighting system have to be able to execute the basic tasks such as, switch on/off, control the luminosity (when it is possible), measure and control the lamp long life. From the analysis made in correlate works, it is possible to divide the requirements into the following.

- Supervision: Lee et al. [3] illustrate a typical example of how a management app can dispose the information about lamp condition in real-time through a graphical perspective, in which the user can easily identify the operation conditions of a branch into the network. The Streetlight Vision company app, for instance, monitors and anticipates the end of a lamp working life by supervising its state. Denardin et al. [2], Leccese and Leonowicz [5] and Long et al. [6] affirm that, besides supervising the operation condition of lighting points in real-time, the system was also able of monitoring the variables of lamp consumption.
- Operation: operations such as switch on/off and control of lamp luminosity are resources met in the companies Central Software apps — Street intelligence Inc. [7], EpiSensor [8], Strategic Telemetry [9] and Streetlight Vision [4]. Such operations are made individually, meaning that only one node sensor is selected and the command is sent only to that device, previously specified. Streetlight Vision [4], Leccese and Leonowicz [5] and Long et al. [6] emphasize that the public lighting system can, according to the user need, set the unitary or group control of node sensor, it means that a determined command is applied to many nodes simultaneously, which enables a higher productivity to the system operator
- Alarms: Long et al. [6] affirm the system management app installed in the control center must be able to bear alarms for abnormal operation conditions. The company Streetlight Vision [4] suggests that the resource of alarm manipulation such as its configuration be stored in a data base. Our purpose has a limitation, since there is no a notification mechanism to the user; due to that, reports or screen alarms must be consulted in order to check the occurrence of any alarm.
- Remote operation: in the work of Chunguo et al. [10] the limitation on the using of ActiveX controls in Internet browsers, which is considered an unsafe solution as it enables external invasion to the computer through the network, can be cited. ActiveX is a technology that belonged to Microsoft that enables its browser Internet Explorer to show and dospose contents in HTML pages. The apps by Central Software — Streetlight intelligence Inc. [7] and Street Vision [4] dispose the complete system control by Internet, enabling the authorized users to operate it remotely. On the other hand, Zotos et al. [11] has the system conception management and monitoring by Internet.
- Supportability: the functions available in a node sensor are distinct among manufacturers. In order for a management app to work fully and dospose the functionalities of devices to the user, it is necessary for the manufacturer to describe the functionalities in a common standard. The integration of new sensor node models enables the management app to supervise/control sensor nodes with different functionalities. Sensor node manufacturers can develop their equipment and integrate them in solutions without any need of additional modifications in the management app. This requirement is normally implemented through the description files, which describe all the device information to be integrated in the system.

3. Requirements for public lighting system operation

Follow below all the requirements proposed for public lighting system operation.

- Remote operation: the user must operate the system through an Internet browser, named as remote operation app.
- Alarms: the armed sensor nodes must be listed and positioned in maps. A burnout light is a typical alarm. The user will be able to configure the alarm visualization, hiding the unwanted alarms. Moreover, all the occurrences must be listed in report papers.
- Operating state: the remote operation app must list the operating state of all lamps (switched on/off) and position each of them in the map. The user will be able to configure the operating state visualization. For instance, the user can filter out from the visualization all the switched on lamps so, by doing that, the only lamps shown, will be the switched on ones or vice versa. As a result, it is possible during the day light to detect which lighting points need intervention to be reset to their regular working.
- Individual operating: when selecting a node sensor, it enables to supervise the values of all their parameters and configure them. An example of a configurable parameter is the node sensor operation; be it automatic or manual. In the automatic mode, the photocell relay controls when the lamp is switched on/off, in function of the presence of luminosity or not. However, in the manual mode, the user can specify a timetable for the lamps to be switched on/off.
- Group operating: the group operating is a requirement to configure multiple sensor nodes simultaneously. A geometric figure (circle or rectangle) is drawn in the graphical interface and all the sensor nodes in the area will be configured. A typical application case is when it is wanted to switch on/off the lamps of a street/block. Without this requirement, the user would have to configure individually several street/block sensor nodes;
- Consumption: measures and presents the consumption in a graphical format daily and monthly;
- Supportability: in the fieldbus protocols scenery, the capability of bearing different models from different sensor node manufactures (interoperability) is a real necessity. Analogically, this requirement needs to be incorporated to the system. The solution would be the manufacture to describe all the node sensor features in a description file. The supportability would happen when the description file is transferred and integrated to the system, which would pass all the information needed from the device by offline mode.
- Standardization: correlated works in their majority, do not apply standards for supervision, which would guarantee the interoperability among the apps and systems. However, the authors Atici et al. [12] present a centralized architecture in the server OPC-DA (OPC Data Access) [13,14], multiple segment of sensor nodes communicate to the server OPC-DA, disposing their variables. The server OPC-DA facilitates the sensor nodes supervision maintenance. Moreover, another advantage of adopting an OPC-DA server is the ability of expanding the system, so multiple servers can be managed by only one management app, centralizing the system management process. The standardization of communication between the management app and the communication controller permits architecture: open, distributed, easy to maintain and expansible.

Information exchanged between the app and the OPC-DA is in binary format, which limits the application in the Internet because the firewalls restrict this kind of information. Therefore, posteriorly, the following standards were created OPC XML-DA (OPC XML Data Access) and the CyberOPC [15], especially gotten for the data exchange remotely, in unsafe environments.

Torrisi [16] presents a comparative study between OPC XML-DA and CyberOPC. He concludes that the CyberOPC provides similar services (reading and writing) to OPC XML-DA. However, the CyberOPC offers