Management Studies, Sep.-Oct. 2023, Vol. 11, No. 5, 245-252
doi: 10.17265/2328-2185/2023.05.001

IoT for Streetlighting—Requirements for Modelling of Management Services—Part I

Mila Ilieva-Obretenova
University of Mining and Geology, Sofia, Bulgaria
Radi Pipev
"Sofia-Project" Municipal Company, Sofia, Bulgaria

Energy conservation is the effort to reduce the overconsumption of energy by the usage of less energy services. Energy conservation could be user oriented or industry sector oriented. One of these sectors is the streetlighting—major energy consumer in the town—forming nearly 30% of each country's consumption. Intelligent designed management of streetlighting not only reduces the energy consumption of the town, but also increases the public safety and the wellbeing. The article focuses the management of IoT for streetlighting in smart city. This is the first stage of project "Service management for IoT in streetlighting". While the basic management principles are efficiency and fairness, the requirements of all actors must be defined. On the base of requirements, the authors synthesize the management functions with selected granularity. The chosen methodology is unified modelling language (UML): use case diagrams. The models are intended to business developers, university professors, and students.

Keywords: streetlighting, IoT, requirements, management system, UML

Introduction

Streetlighting is one of the most energy intensive structures in a town and therefore it is economically overtaxing for the administration. The conventional approach to streetlighting is inefficient because it does not consider the environmental factors as illumination level and traffic flow. Therefore, it is necessary to implement information and communication technologies like Internet of Things (IoT) for management of energy consumption and operating costs. The term "Internet of Things (IoT)" is coined from Kevin Aston in 1999: the network connecting objects in the physical world to the Internet (Gabbai, 2015). Actually, it becomes one of the concepts that transform our surroundings more and more intelligent. It is heavily affecting people's daily lives in many domains (Boulaalam, 2019). Sanchez, Elicegui, Cuesta, Muñoz, and Lanza (2013) describe the integration of IoT with the traditional utility infrastructures. One of them is the street lighting network. Dizon and Pranggono (2022) analyze the implementation of IoT in streetlights, divided into three stages corresponding to the three layers described in Lin et al. (2017), Wu, Lu, Ling, Sun, and Du (2010), and Yang et al. (2011). There is no layer Business management in these hierarchies which could include: planning money for sensors and

---

Mila Ilieva-Obretenova, Ph.D., associate professor, Department Automation of Production Systems, University of Mining and Geology, Sofia, Bulgaria.
Radi Pipev, MS, Head of Outdoor and Traffic Lights Department, "Sofia-Project" Municipal Company, Sofia, Bulgaria.
Correspondence concerning this article should be addressed to Mila Ilieva-Obretenova, University of Mining and Geology, Boyan-Kamenov-Str., Sofia 1700, Students City, Bulgaria.

controllers, reducing the staff for maintenance and repair, calculating the average price of energy consumption per hour, calculating the average expenditure for a year, calculating the energy conservation, calculating the savings in kWh and in money, forecasting the adequacy of photovoltaics for energy conservation. In Table 1, the three stages in implementation of IoT in streetlights are illustrated.

This model, however, does not consider the functional areas for management, as it is shown in European program for development of communications (RACE) (Magedanz, 1994). This model classifies in detail which functions participate in the life cycle of the service: functional areas on OSI (configuration, maintenance, performance, accounting and security) and other defined areas (project and planning, installation, provision and user control). Figure 1 depicts the functional areas for management of telecommunications according to program RACE.

Table 1

Three Stages in Implementation of IoT in Streetlights [4] (Dizon & Pranggono, 2022)

1st stage—perception layer	Wireless Sensor Networks (WSN) to monitor data on the environment Light sensors to monitor the light level Rain gauge to measure precipitation Wind direction vane and anemometer to measure the wind speed and direction Water level to measure ground water level for flooding Environmental air pollution detector to measure traffic pollution
2nd stage—network layer	WSNs able to receive and retransmit data from gateways, ZigBee/WLAN based communication protocol used to communicate between neighbouring WSNs, creating a mesh network WSN communicates to other gateways creating a larger network The use of Wi-Fi and GPS to transmit data from a base station to the cloud which can be accessed by a central control and monitoring system
3rd stage—application layer	Responsive measures can be taken based on the data gathered Alerting authorities if water level is high Dimming of streetlights if surrounding level is high Monitoring traffic based on air pollution levels Monitor air levels for any toxic gas present and will alert authorities if present

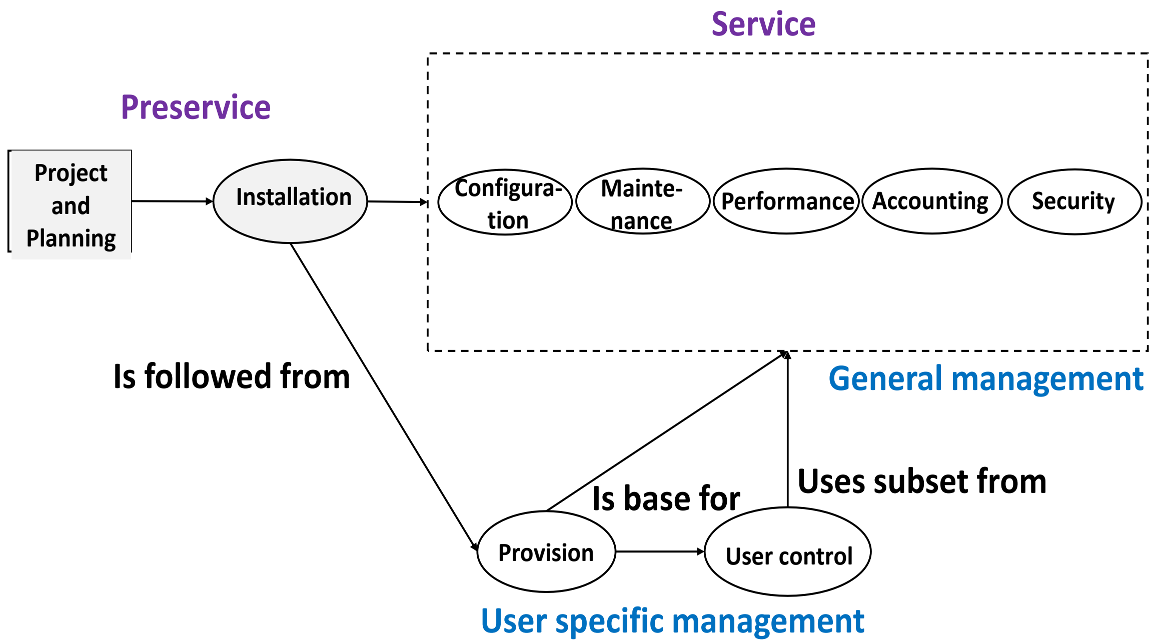

Figure 1. Functional areas for management on RACE program.

Ilieva-Obretenova (2018) shows the application of RACE functional areas for city monitoring by smart streetlighting. Disadvantage of the research is the lack of energy conservation assessment. In inteliLIGHT (2023) and TALQ Consortium (2023) management systems for streetlighting with IoT are discussed, but man can add some new functions. Asif et al. (2022) represent streetlight control system using IP-cameras and deep learning image recognition and traffic forecasting. The authors focus on network element management. Service management for municipality officer is missing. Al-khaykan, Aziz, Al-Kharsan, and Counsell (2022) prioritize network elements (lamps) and their management. Bakri et al. (2022) also evaluate network elements (intelligent controller) and its management with deep learning. The service management and the business management are missing. Jagadeesh, Akilesh, Karthik, and Prasanth (2015) examine sensor-based streetlights with dynamic and their management. The network management is missing. Alabani (2018) comments on the replacement of (high-pressure sodium) HPS lamps with LED and the integration of control node (dynamic dimmer). The intelligence is missing in this system. Yaichi et al. (2022) recommend smart street lighting system with network management. It needs more detailed service management. Askola, Kärhä, Baumgartner, Porrasmaa, and Ikonen (2022) organize network element management and the paper lacks network and service management. Arshad et al. (2020) generalize evolution and implementation of IoT based smart streetlights. The study needs more detailed management paradigm. The recent article has the aim to define requirements for management of IoT for streetlighting considering all actors in the process, and the transformation of the requirements into management functions.

Methodology

On the base of requirements of all actors, authors define high level management functions by using UML (Unified Modelling Language) (Fowler, 2004; StarUML, 2022). UML diagrams are classified in two categories: behavioural diagrams and structure diagrams. On the first stage authors use behavioural diagrams and especially use case diagrams. Use case is a technic for setting the functional requirements to one system. Use cases trace the typical interconnections between the users and the system, providing a description of the way how it is used. The authors have still experience with use cases (Ilieva-Obretenova & Chaudhary, 2020).

Results

The working conditions of the system for management of IoT for streetlighting are established from some actors: network operator (sometimes includes network element operator too), service provider, municipality officer, and head of department in the municipality. Network operator manages the classical network for streetlighting and IoT network. The provider manages the services (applications) for IoT and uses network resources, provided from operator. The officer in municipality has requirements to the provider for services and options for service management. For the usage of service management for IoT the officer needs a connection to the classical network of streetlighting. The head of department in the municipality has requirements for business management. He/she does not need a connection to the classical network of streetlighting. For each actor management services must be synthesized. Actors' requirements to the corresponding management services are synthesized from the set theory (Hernandez, 2013; Date, 2003; Garcia-Molina, Ullman, & Widom, 2002).

For better clarity the network element operator and the network operator are divided, and their requirements are defined separately. The sets with actors' requirements are signified as follows:

R—set with requirements to the whole system

R_{one}—set with requirements of the network elements operator

R_{on}—set with requirements of the network operator

R_p—set with requirements of the service provider

R_s—set with requirements of the officer in the municipality

R_m—set with requirements of the head of department in the municipality

The set with requirements to the whole system is equal to the integration of all sets with requirements.

$$R = R_{one} \cup R_{on} \cup R_p \cup R_s \cup R_m$$

There is a surjection between the sets with requirements of the actors (Hernandez, 2003). The network elements operator has most of all requirements, i.e., his requirements are the superset. Network operator's requirements are subset of them i.e., the network operator applies only a part of the network element operator's requirements. Service provider's requirements are a subset from these of network operator. Municipality officer's requirements are a subset from these of the service provider. Head of department's requirements are a subset from these of the municipality officer.

$$R_m \subset R_s \subset R_p \subset R_{on} \subset R_{one}$$

The precise requirements to management services are:

- R_{one}—Operator's requirements to network element management
  - R_{one1}—Requirements for visualisation network element management; They are realised by functions for network element management.
  - R_{one2}—Requirements for automatic interconnections with other layers (management of electrical network and service management); They are realised by interconnections between functions for network element management, provided to operator, and management functions, provided to municipality officer and to electrical network operator.
  - R_{one3}—Requirements for interconnections between functional areas; They are realised by interconnections between functions for network element management.
  - R_{one4}—Requirements for interconnections between layer network element management and layer network element; They are realised by interconnections between functions for network element management and functions for network element representation.
  - R_{one5}—Requirements for interconnections between network element management and network element unit; They are realised by interconnections between functions for network element management and functions, representing network element units.
  - R_{one6}—Requirements for visualisation of network element management for a service; They are realised by functions for network element management for a service.
  - R_{one7}—Requirements for interconnections between functional elements; They are realised by interconnections between functions for functional element access management.
- R_{on}—Operator's requirements to network management
  - R_{on1}—Requirements for visualisation of network management; They are realised by functions for network management, provided to operator, on functional areas.
  - R_{on2}—Requirements for automatic interconnections with supreme actor-provider; They are realised by interconnections between functions for network management from operator and functions for management of service provider.
  - R_{on3}—Requirements for interconnections between functional areas; They are realised by interconnections between functions for management of network profile.

- R_{on4}—Requirements for interconnections between layer network management and layer network element management; They are realised by interconnections between functions for network management for a service and functions for network element management.
- R_{on5}—Requirements for interconnections between layer network management and layer network element; They are realised by interconnections between functions for network management and functions, representing network elements.
- R_{on6}—Requirements for visualisation of network management for a service; They are realised by function for network configuration for a service.

- R_p—Provider's requirements to service management
  - R_{p1}—Requirements for visualisation of service management; They are realised by functions for service management, provided to provider on functional areas.
  - R_{p2}—Requirements for automatic interconnections with supreme actor-municipality officer; They are realised by interconnections between functions for service management from provider and functions for management of officer's profile.
  - R_{p3}—Requirements for interconnection between functional areas; They are realised by interconnections between functions for management of service profile.
  - R_{p4}—Requirements for interconnections between layer service management and layer network management; They are realised by interconnections between functions for service management, provided to provider, and functions for network management, provided to operator.
  - R_{p5}—Requirements for interconnections between layer service management and layer network element management; They are realised by interconnections between functions for service management, provided to provider, and functions for network element management, provided to operator.
- R_s—Municipality officer's requirements to service management
  - R_{s1}—Requirements for visualisation of service management; They are realised by functions for management of officer's profile.
  - R_{s2}—Requirements for automatic interconnections with supreme actor-head of department in municipality; They are realised by interconnection between function for management for officer and function for management of head of department's profile.
  - R_{s3}—Requirements for interconnection between functional areas; They are realised by interconnections between functions for management of officer's profile.
  - R_{s4}—Requirements for interconnections between layer service management for officer and layer service management; They are realised by interconnections between functions for service management, provided to the officer, and functions for service management, provided to provider.
- R_m—Head of department's requirements to business management
  - R_{m1}—Requirements for visualisation of business management; They are realised by functions for management of head of department's profile.
  - R_{m2}—Requirements for interconnection between functional areas; They are realised by interconnection between functions for management of head of department's profile.
  - R_{m3}—Requirements for interconnections between layer business management and layer service management; They are realised by interconnections between functions for business management, provided to the head of department, and functions for service management, provided to the officer.

Figure 2 depicts surjection between the elements of requirements sets.

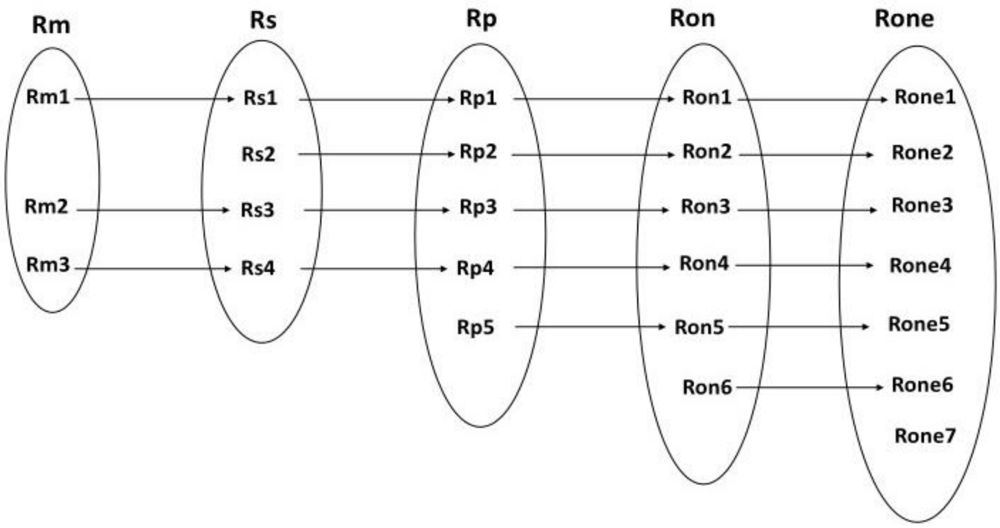

Figure 2. Surjection between the elements of requirements sets.

On the next step the synthesized actors' requirements are transformed into management functions. Each function is represented as use case, corresponding to management functional area from Figure 1. The functions for service installation, provided to service provider (ServiceProvider) are the following:

Function IntroServ(x) offers service introduction.

Function ArrangeF(x) outlines service feature arrangement.

Function InstallServProf(x) defines service profile installation.

Function ConfigureServ(x) states service configuration.

Function MaintainServ(x) identifies service maintenance.

Function SecureServ(x) summarizes service security.

Function AccountServ(x) explain service accounting.

Function PerformServ(x) express monitoring of service performance.

Figure 3 shows UML diagram of use cases for service installation.

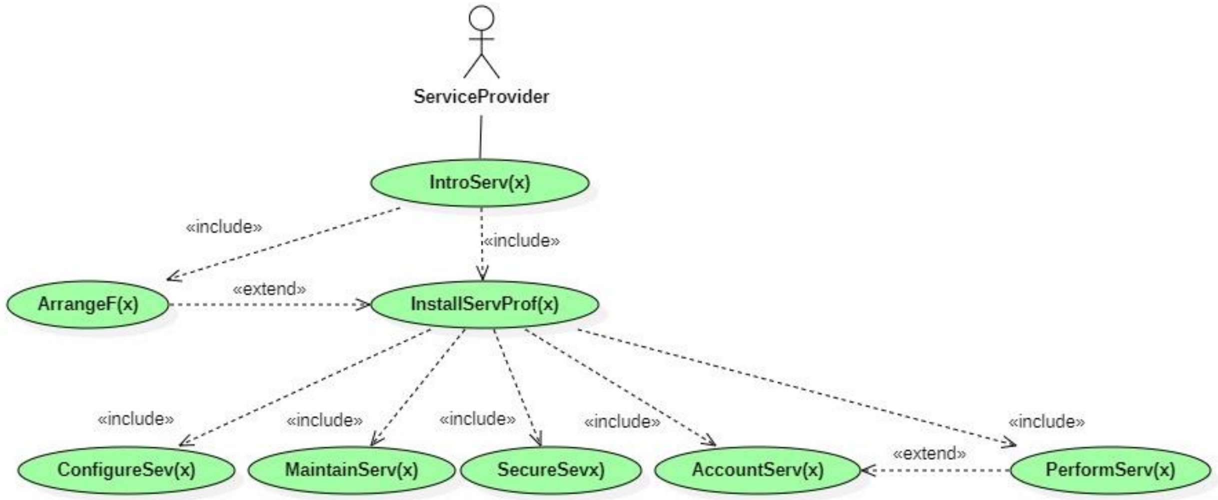

Figure 3. UML diagram of use cases for service installation.

Conclusion

Energy conservation, reduction of carbon emissions, and of light pollution are key issues of modern society. Administration of these processes needs balancing mechanism for rights and duties between all actors. The article represents the synthesis of requirements to IoT management for streetlighting for each participant. On the next step the requirements are transformed into high level management functions for each layer of IoT network and for each functional area from the lifecycle. The functions are illustrated by use cases for functional area installation on layer service management. The future work includes development of use case diagrams for all functional areas on all layers inclusive business management, considering the geographical characteristics and climate changes by planning energy conservation.

References

Alabani, S. (2018). Energy saving potential of dynamic lighting control in street lighting systems in Libya. *Solar Energy and Sustainable Development Journal, 7*(1), 12-17. Retrieved from https://doi.org/10.51646/jsesd.v7i1.33

Al-Khaykan, A., Aziz, A. S., Al-Kharsan, I. H., & Counsell, J. M. (2022). New methodology to reduce power by using smart street lighting system. *Open Engineering, 12*(1), 918-922. Retrieved from https://doi.org/10.1515/eng-2022-0361

Arshad, S. R., Saeed, A., Akre, V., Khattak, H. A., Ahmed, S., Khan, Z. U., Khan, Z. A., Nawaz, A. (2020). Leveraging traffic condition using IoT for improving smart city street lights. In Proceedings of the *2020 IEEE international conference on communication, networks and satellite (COMNETSAT)* (pp. 92-96). Batam, Indonesia. doi:10.1109/Comnetsat50391.2020.9329004

Asif, M., Shams, S., Hussain, S., Bhatti, J. A., Rashid, M., & Zeeshan-ul-Haque, M. (2022). Adaptive control of streetlights using deep learning for the optimization of energy consumption during late hours. *Energies, 15*, 6337. Retrieved from https://doi.org/10.3390/en15176337

Askola, J., Kärhä, P., Baumgartner, H., Porrasmaa, S., & Ikonen, E. (2022). Effect of adaptive control on the LED street luminaire lifetime and on the lifecycle costs of a lighting installation. *Lighting Research & Technology, 54*(1), 75-89. doi:10.1177/14771535211008179

Bakri, B. I., Abid, Y. M., Ali, G. A., Mahdi, M. S., Omran, A. H., Jaber, M. M., Jalil, M. A., & Kadhim, R. A. (2022). Using deep learning to design an intelligent controller for street lighting and power consumption. *Eastern-European Journal of Enterprise Technologies, 3*(8), 25-31. Retrieved from https://doi.org/10.15587/1729-4061.2022.260077

Boulaalam, A. (2019). Internet of things: New classification model of intelligence. *J Ambient Intell Human Comput., 10*, 2731-2744. Retrieved from https://doi.org/10.1007/s12652-018-0965-2

Date, C. J. (2003). *An introduction to database systems* (8th Ed.). New York: Addison Wesley Longman, Inc. ISBN:978-0-321-19784-9

Dizon, E., & Pranggono, B. (2022). Smart streetlights in smart city: A case study of Sheffield. *J Ambient Intell Human Comput., 13*, 2045-2060. Retrieved from https://doi.org/10.1007/s12652-021-02970-y

Fowler, M. (2004). *UML distilled: A brief guide to the standard object modelling language* (3rd Ed.). Addison: Wesley Professional.

Gabbai, A. (2015). Kevin Aston describes “the Internet of Things”. *Smithsonian Magazine*, January, 2015.

Garcia-Molina, H., Ullman, J. D., & Widom, J. (2002). *Database systems: The complete book.* Hoboken: Prentice Hall, Inc.

Hernandez, M. J. (2013). *Database design for mere mortals* (3rd Ed.). New York: Addison Wesley. ISBN-13:978-0-321-88449-7

Ilieva-Obretenova, M. (2018). Information model for city monitoring by smart lighting. *Journal of Mining and Geological Sciences, 61*, 55-59. ISSN 2535-1192

Ilieva-Obretenova, M., & Chaudhary, M. P. (2020). Scenarios for blockchain transactions in smart grid. *The Mathematics Education India, 55*(4), 145-159. ISSN 0047-6269

inteliLIGHT® (2023). StreetLight Control Software: Remote Management Software.

Jagadeesh, Y. M., Akilesh, S., Karthik, S., & Prasanth. (2015). Intelligent street lights. *Procedia Technology, 21*, 547-551. ISSN:2212-0173. Retrieved from https://doi.org/10.1016/j.protcy.2015.10.050

Lin, J., Yu, W., Zhang, N., Yang, X., Zhang, H., & Zhao, W. (2017). A survey on internet of things: Architecture, enabling technologies, security and privacy, and applications. *IEEE Internet of Things Journal, 4*(5), 1125-1142. Retrieved from https://doi.org/10.1109/JIOT.2017.2683200

Magedanz, T. (1994). *An integrated management model for intelligent networks.* Munchen, Wien: Oldenburg,

Mouaadh, Y., Bousmaha, B., & Mhamed, R. (2022). Intelligent control and reduce energy consumption of smart street lighting system. *International Journal of Power Electronics and Drive Systems, 13*(4), 1966-1974. ISSN:2088-8694. doi:10.11591/ijpeds.v13.i4.pp1966-1974

Sánchez, L., Elicegui, I., Cuesta, J., Muñoz, L., & Lanza, J. (2013). Integration of utilities infrastructures in a future internet enabled smart city framework. *Sensors*, *13*, 14438-14465. Retrieved from https://doi.org/10.3390/s131114438

StarUML. (2022). MKLabs Co., Ltd. Version 4.1.2.

TALQ Consortium. (May 3 2023). Improved manageability for smart outdoor lighting. Retrieved from https://www.talq-consortium.org/data/downloadables/4/6/0/pr-talqspecification-realise-2-5-0-20230503-en.pdf

Wu, M., Lu, T. J., Ling, F. Y., Sun, J., & Du, H. (2010). Research on the architecture of internet of things. In *3rd international conference on advanced computer theory and engineering (ICACTE) (pp. V5-484–V485-487)*, 20-22 Aug. 2010. Retrieved from https://doi.org/10.1109/ICACTE.2010.5579493

Yang, Z. H., Yue, Y. Z., Yang, Y., Peng, Y. F., Wang, X. B., & Liu, W. J. (2011). Study and application on the architecture and key technologies for IOT. In *2011 international conference on multimedia technology* (pp. 747-751), 26-28 July 2011. Retrieved from https://doi.org/10.1109/ICMT.2011.6002149