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IoT Management for Street Lighting—Information Model—Part II

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Design is a concept of either an object, a process, or a system that is specific and, in most cases, detailed. A service design is designing or organizing the experience around a product and the service associated with a product’s use. For this purpose, service design uses methods and tools derived from different disciplines like information and management science. The second level of management science is about building models and implementing models on computers. The paper presents the second stage of project “Service management for IoT in streetlighting”. From several points of view a review of streetlighting management is performed: (1) design and spending; (2) network element management; (3) network management; (4) new technologies in smart streetlighting. The authors synthesize main objects classes for service management and specialized managed objects classes for two areas—Service Provision and Officer control. The used design methodology is unified modelling language (UML) and particularly class diagrams. The models are intended for business developers, university professors, and students.

Keywords: service management, IoT, smart streetlighting, managed objects classes, UML

Introduction

The management of IoT for street lighting has the aim to ensure the safe travel of people and vehicles on the road. The literary sources for street lighting management could be merged in the following basic topics. (1) Design and Spending: Electrical4U (2020) describes street lighting design, but without concept for energy conservation. Kurt and Kiyak (2021) analyse a control system for street lighting with different scenarios. These scenarios are detection motion at night, detection at rising sun, no motion at night, no motion at rising sun, and enough illumination. The next step could be service management design. In Askola, Kärhä, Baumgartner, Porrasmaa, and Ikonen (2022) authors estimate that the lifecycle costs of an adaptive street lighting reduce by 25% as compared to a similar LED luminaire installation without traffic-aware control, outweighing the costs due to the reduced lifetime. Only user-friendly interface for business management is missing. (2) Network element management: Mouaadh Bousmaha, and Mhamed (2022) show a scenario for smart control on LED,

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controlled by motion sensor and controller with 50% energy saving. Sadri and Fereidunian (2022) focus on Infra-Red (IR) sensors and LED, controlled by Arduino Uno board, in smart adaptive street lighting. Ram Kumar et al. (2021) prioritize management of Light Dependent Resistor (LDR), which detects the movement of the vehicle and turns the corresponding streetlights on and off accordingly when the vehicle passes away. In all these solutions the paradigm for network management is missing. (3) Network management: StartUsInights (2019) performs a comprehensive review of five startups. The most interesting is Citintelly-Latvian system for street lighting control. It visualizes data from streetlights' controllers in a web interface and describes cloud-based management system. Smart Energy International (2009) considers software suit, which offers user friendly tools for control, configuration, and reporting of the lighting network operation. In Jagadeesh, Akilesh, Karthik, and Prasanth (2015) the existing streetlighting network is combined with intelligence to think itself. In Anguraj, Balasubramaniyan, Saravana Kumar, Vakula Rani, and Ashwin (2022) renewables are added to the streetlighting structure—solar panels and wind turbines. A system with Artificial Intelligence (AI) elements controls the energy consumption of adaptive street lighting. In all these solutions the integration with service management is missing. (4) New technologies in street lighting: The most literary sources accent on IoT as a concept for streetlighting control. In Lighting Manufacturer (2023) streetlamp monitoring devices, Narrow Band-IoT (NB-IoT) network connections, a central IoT platform, and an operation management are represented. Arshad et al. (2020) demonstrate in detail how IoT works smart and modifies the streetlight poles based on traffic conditions. Martinez et al. (2021) discuss the benefits of new technologies in street lighting systems: not only IoT, but also image processing and renewable energies. In Marufa (2021) IoT-enabled Hybrid Renewable Energy System (IoT-HRES)-based green highway lighting system is discussed. The proposal manages the green energy smartly, reduces solar dependence, controls the lighting according to the traffic demand, and performs backtracking detection of the faulty lamppost. A simulation investigates the two popular communication module technologies: LoRa and IEEE 802.15.4. In all these solutions integration with business management is missing. The aim of this article is to synthesize model for service management in IoT for streetlighting, to show the transformation of use cases in managed objects classes, and to list managed objects for one selected area—Officer control.

Methodology

In this paper developed models for management of IoT for street lighting are represented and particularly service management model. By defined high level management functions a functional decomposition of responsibilities to the management for each actor is completed. Modelling is based on generalisation of existing management functions and synthesis of new ones, covering the requirements in all management areas. Object-oriented approach is applied. Managed objects classes are defined, corresponding to managed units. Guidelines for Definition of Managed Objects (GDMO) are followed (ISO/IEC/IS, 1989) according to network management standards. For models' description Unified Modelling Language (UML) (Fowler, 2004; StarUML, 2022) is used, particularly class diagrams. Class diagram describes the object types in the system and the different relationships between them. They also show the features and operations of classes and the limits in connections between the objects. Features are one term, but the presentation has two different notations: attributes and associations. The attribute notation describes a certain feature as a text line in the rectangle for a class. The association is a line between two classes. Its direction is from class-source to class-aim. The feature's name is set on the purpose end of the association together with its majority. The purpose end relates to the class, which is the type of feature.

The majority of a feature means how many objects could complete the feature. Operations are the actions a certain class could perform. There is a difference between operation and method. Operation is invoked for a method—procedure declaration. Method is the code of procedure. Both are different by polymorphism—one interface for different data types. The biggest danger by class diagrams is the concentration on the structure and the underrating of the behaviour. Therefore, class diagrams must be always combined with behaviour technic like use case diagrams. The authors have experience with UML (Ilieva-Obretenova, 2021).

Results

This paragraph depicts UML diagram of use cases for service provision, from which a diagram of Managed Objects classes is synthesised.

Service provider and Municipality officer are direct participants in service provision. The Head of department (business user) acts indirectly by the officer.

Function SignOfficerContr(x) considers the contract signing between officer and service provider.

The other functions completed from the provider are the following:

Function ManageServ(x) represents the service management during the provision to the officer.

Function ManageF(x) organizes the choice of features, provided to the officer.

Function ManageServProf(x) generalizes the management of service profile during the provision to the officer.

Function ConfigureServ(x) traces the configuration of the service.

Function MaintainServ(x) states the maintenance of a service.

Function SecureServ(x) names the security of a service.

Function AccountServ(x) labels the accounting of a service.

Function PerformServ(x) identifies the monitoring of service performance.

Function InstallOfficerProf(x) summarizes the installation of officer’s profile.

Functions completed from the municipality officer are the following:

Function InstallOfficerProf(x) illustrates the settings of officer’s profile.

Function ConfigureOfficer(x) explains the configuration of the officer.

Function MaintainOfficer(x) expresses the maintenance of officer’s services.

Function SecureOfficer(x) presents the security of officer.

Function AccountOfficer(x) analyses the accounting of officer’s services.

Function PerformOfficer(x) considers the reporting of signed performance parameters of the contracted services.

Functions InstallBusinessProfile(x) supports the installation of business user profile.

Functions provided to user of business services are the following:

Function InstallBusinessProfile(x) is for settings of business user profile.

Function AccountBusiness(x) organizes the accounting of business.

Function PerformBusiness(x) generalizes the reporting of service parameters, used from business.

Figure 1 shows UML diagram of use cases for service provision.

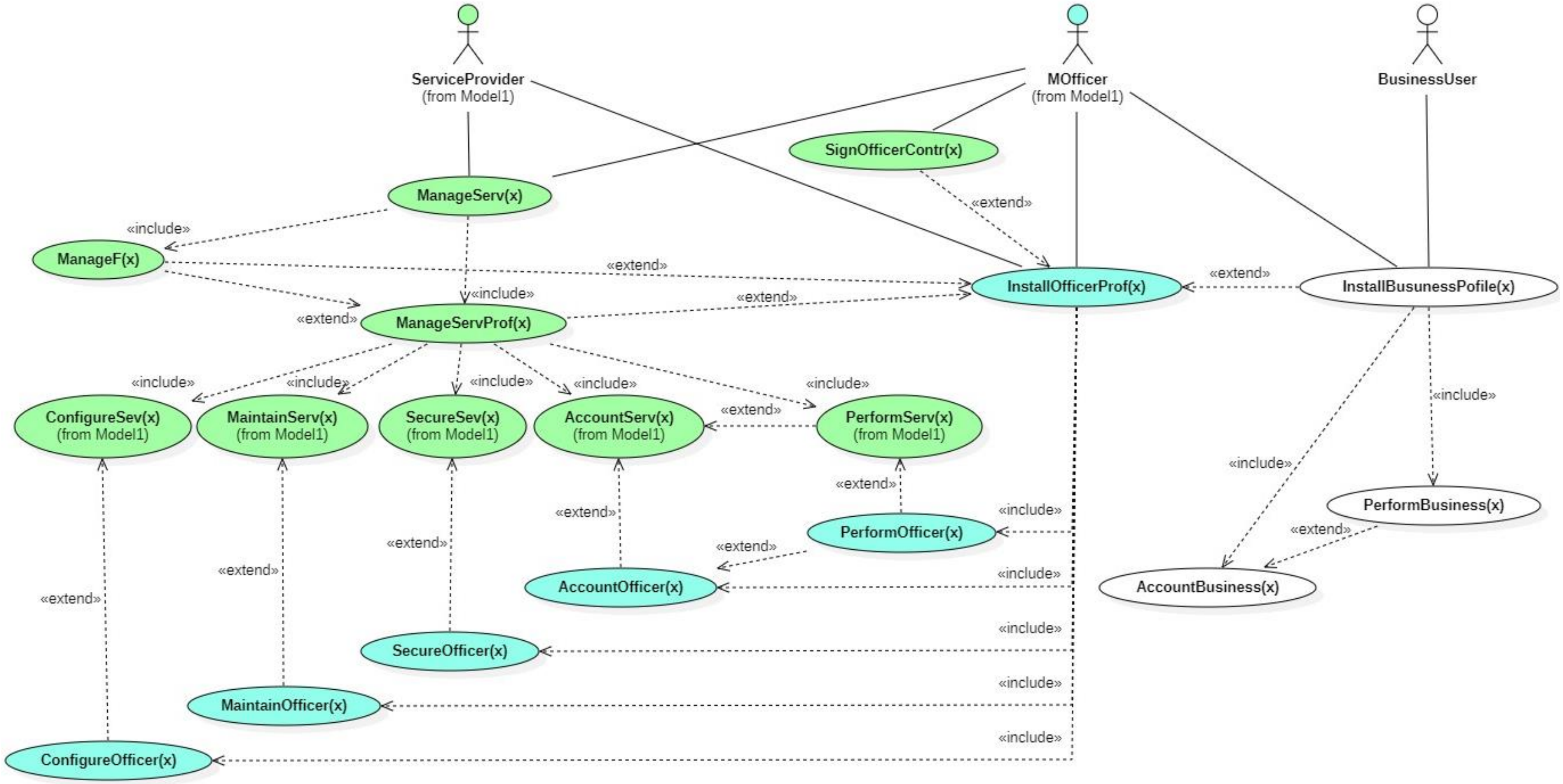

Figure 1. UML diagram of use cases for service provision.

Main Objects Classes

In this paragraph Managed Objects (MO) classes are defined for the actors, the object of management, and the way of management for street lighting by IoT. The actors are: service provider—MO ServiceProvider, municipality officer—MO MOfficer, and head of department—MO BusinessUser. Objects of management are: IoT service—MO IoTService, the officer, and the head of department. Objects of management are controlled by profile—MO Profile. Elements of management are expressed by functional areas in Open Systems Interconnection (OSI): MO Configuration, MO Maintenance, MO Security, MO Accounting, and MO Performance. The managed objects for service are depicted in Figure 2.

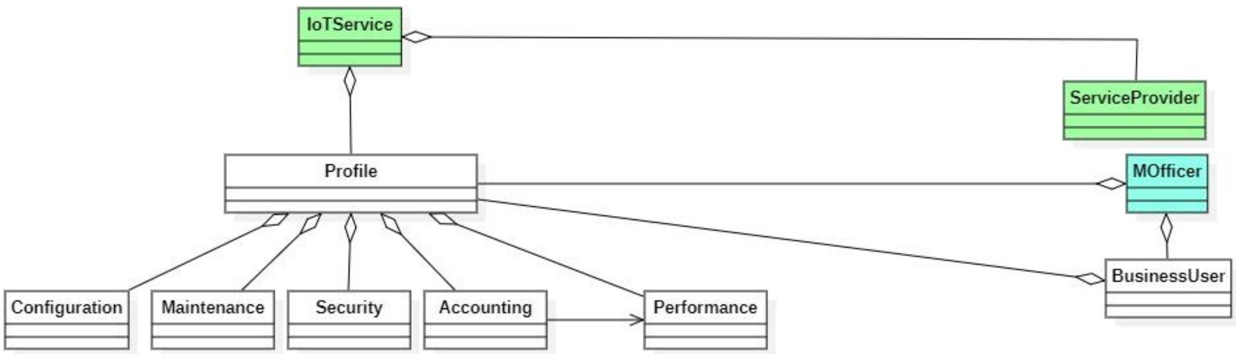

Figure 2. UML diagram of main objects classes for service management.

Inherited Objects Classes

Managed objects classes for service provision. Managed Objects from provider's side are the following:

MO ServiceProvider consists of information about a company, which produces, sells, and/or supports telecommunication services.

MO IoTService represents a description of service's features form provider's point of view. The specification considers certain functionality, which could be provided to one or more municipalities. The services could be four types: (1) The street lighting has established periods of dimming, based on geographical location. For instance: 18:00-20:00—90% illuminance output, 20:00-23:00—65%, 23:00-5:00—40%, 5:00-6:00—55%. (2) Only one step of dimming and the duration could be changed according to observations. For instance: between 22:00 and 5:00 the street lighting will have 65% illuminance output. This scheme will be effective in rural areas or in regions with a little traffic during the night. (3) Part-night lighting scheme: The street lighting is switched off during periods of the night. This scheme is suited for areas without potential hazards and the street lighting is switched off between 24:00 and 5:00 during the week and between 1:00 and 6.30 during the weekends. (4) Adaptive scheme called "traffic aware lighting scheme". It uses an autonomous Wireless Sensor Network (WSN) to detect the traffic flow and act upon street lighting. The scheme quantifies the switch on of street lighting by considering different road users—pedestrians and motor vehicles. The adapting lighting scheme for a pedestrian is the following: It creates descending light distribution, so streetlights within the vicinity have maximum illuminance output, whilst those further away will decrease in segments. When the pedestrian is within a streetlight's sensor range [default 13 m], streetlights within a 30 m distance will have a brightness of 100%. After each 30 m segment from the pedestrian, the illuminance output will incrementally decrease by 20%. This continues until the distance X is more than 150 m and at this point the streetlight is switched off. The main difference between a motor vehicle and a pedestrian is the speed at which they are traveling, for residential roads the speed limit for a vehicle is typically 50 km/h and a pedestrian in average travels at 5 km/h.

MO ServiceFeature defines description of a service feature. Each service uses one or more features.

MO ServiceProfile comprises all the information about high level service management.

MO ServiceConfiguration states service configuration, necessary for the provider or tailored on specific demand of the municipality.

MO ServiceMaintenance identifies information for service maintenance, which helps to return the service in normal work state in case of failure.

MO ServiceSecurity summarizes the security rights for a service and the data, needed for security management.

MO ServiceAccounting consists of data for service accounting management.

MO ServicePerformance illustrates the recorded and generalized data, necessary for service performance management.

Objects corresponding with municipality officer are: MO MOfficer explains information for a person, which signs a contract with the provider for service acquisition.

MO OfficerProfile expresses all information for service management, connected with the officer. The Profile is the base for officer specific management.

MO OfficerContract represents a legally binding document, which defines the provided services. It regulates the service usage conditions like tariff, accounting, security, performance, and control possibilities.

MO OfficerConfiguration applies the officer's requirements for configuration of provided service.

MO OfficerMaintenance organizes information, corresponding with the faultless work of services.

MO OfficerSecurity generalizes officer's requirements for security.

MO OfficerAccounting traces all details about officer's accounting.

MO OfficerPerformance defines all performance parameters, required from the officer for a service.

MO BusinessUser describes information for a legitimate user of Business Services (Head of Department). This object shows that the Head of department is shortly connected with the officer.

MO BusinessProfile states all the management information, needed for Head of department to complete the corresponding management activities.

MO BusinessPerformance lists the performance parameters, required from Head of department. This object could comprise the following attributes: (1) Before innovation: installed capacity in [kW], operation in hours for one night in [h/n], number of nights in a month. (2) After innovation: operation capacity in [kW], operation in hours for one night [h/n]. Operations could be: (1) Before Innovation: calculation of consumption of electrical energy for one night in [kWh/n], calculation of consumption of electrical energy for one month in [kWh/m]. (2) After innovation: calculation of consumption of electrical energy for one night in [kWh/n], calculation consumption of electrical energy for one month in [kWh/m], calculation of energy savings for a month in [kWh/m], calculation of energy savings for a month in [%]. MO BusinessAccounting names all details about accounting for the Head of department. It could consist of the following attributes: price of electrical energy in [BGN/kWh], investment in [BGN]. Operations could be the following: (1) Before innovation: calculation the consumption in money for one night in [BGN/n], calculation the average price in electrical energy in [BGN/kWh], calculation the average cost for a month in [BGN/m]. (2) After innovation: calculation the consumption in money for one night in [BGN/n], calculation the average price of electrical energy in [BGN/m], calculation the monthly economy in [BGN/m], calculation the redemption period in months or years. Figure 3 shows the synthesised UML diagram of Managed Objects classes for Service Provision.

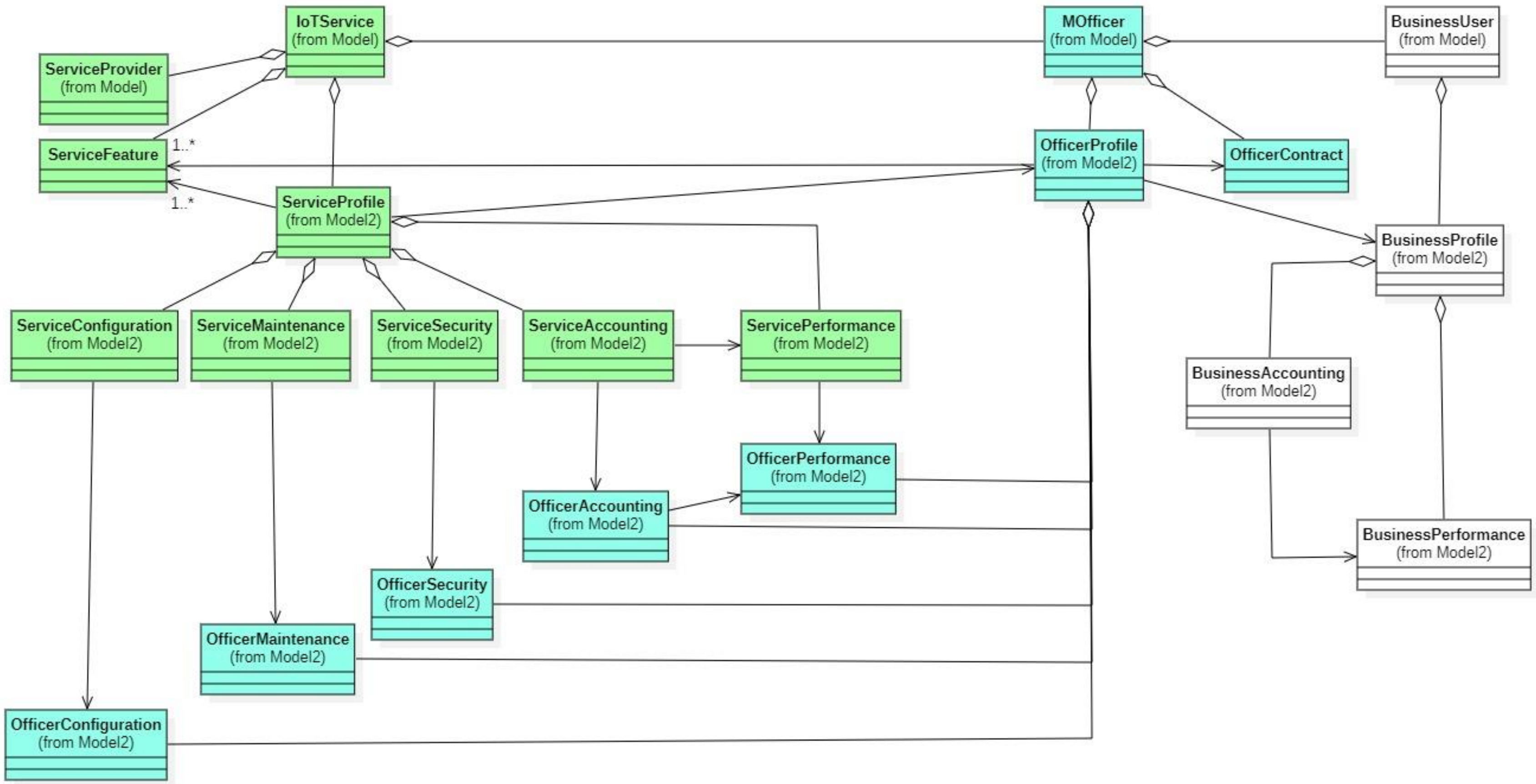

Figure 3. UML diagram of Managed Objects classes for service provision.

Managed objects classes for officer control. Figure 4 shows the synthesised UML diagram of Managed Objects classes for officer control on a service. MO OfficerProfile identifies the objects and the officer completes control on the services with them.

The Managed Objects are the following:

MO RoutingInfo illustrates the information for the location of sensors on the municipality's network.

MO NumberingPlan explains information about numeration of the corresponding sensors. This object is necessary for the separate support of each street.

MO FaultInfo expresses the information about faults connected with this municipality.

MO OfficerComplaint depicts the information for officer's complaint, aroused during the service usage.

MO OfficerAuthorisation represents security rights for the officer and enables the access to his profile and the changes in it. Authorisation could be PIN-code, password, authorisation card, etc.

MO FinancialInfo analyses possible financial information for the officer. The officer could draw up his own report if he has access to certain attributes.

MO Reminder reminds the officer how much money, when, and where he must pay.

MO ChargingMode categorizes regime for specific accounting for the provided services.

MO Limits considers limits to the municipality's account.

MO Payment applies information for the money, paid from the officer after the reminder (the bill).

MO ServiceAccount generalizes information connected with the usage of the basic functionality of IoT from the officer.

MO BearerAccount describes information for the access to the bearer electrical network.

MO ProfileAccount states information for profile changes, made from the officer.

MO QoSInfo identifies the information for parameters, provided to the officer during the service operation.

MO OfficerUsage summarizes the information for service usage from the officer.

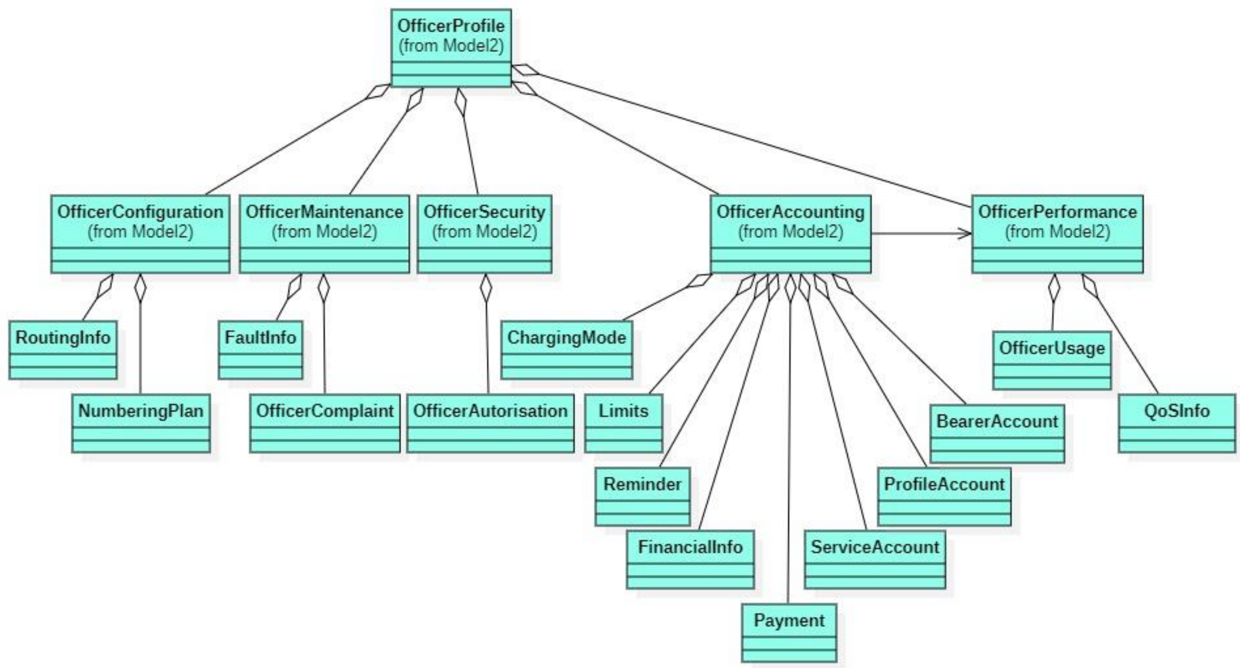

Figure 4. UML diagram of Managed Objects classes for officer control on services.

Conclusion

The paper represents the developed models for service management in IoT for street lighting. Object-oriented approach is applied. Managed objects classes are defined, organised in hierarchy. Links between managed objects are designed. The developed objects could be reused: in one layer—service management or network management; between different layers—service management and network management. The future work could include: design of relational data base, consisting of information for management of services and network; optimization of data base with the aim avoiding data redundancy and anomaly by content update; calculation of energy savings for the different type of services; implementation of a management service; integration of both layers—network management and service management—by service interconnections from both areas.

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