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SMART CITY MANAGEMENT SYSTEM UTILIZAING MICRO-SERVICES AND IOT-BASED SYSTEMS

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Abstract. *Urban governance is without a doubt a very complicated activity. The city doesn't just consist of people and buildings, there are transport and road infrastructure, critical infrastructure, medical facilities, road cover, industrial equipment and many more. Besides, the city council provides a wide range of services to the public. Among them healthcare, welfare, economic and finance supply, labor, real estate management and others. Information management systems and web services are employed for digital management, while various embedded management systems are used for equipment management and surveillance. Being very complex and multilayered system, Smart City Managment solutions offer a platform that encapsulates main services for both public and for technological aspects of urban governance. The results presented in this paper are based on a study of the existing software, hardware and middleware platforms for smart city use case. The main focus is middleware platform as it serves as medium that can connect existing software and hardware solutions. In the global context of Smart city management service system all major components are broken down in the format of microservices (on the level of large enterprise distributed service). Presented Managment software suit model had been broken down into multiple software architecture abstraction layers, from hardware to end-user application. As a result, the three stages smart city service implementation roadmap had been presented. Using the Middleware platform and Web-services models, the Smart City Managment services can be implemented in any given city in porotype stage for future evaluation and full version implementation.*

Key words: ***IoT, AI, smart city, software design, urban governance, embedded systems.***

Introduction. Modern cities are heavily populated, having a lot of technological and electronics equipment in service. City government needs to process large quantities of information while managing and promptly responding to any issue or problem that arises in the city. The previous can't be accomplished without usage of information systems and control over city public equipment (road lights, power supply, waste management, city economy, taxes collection and other services). The exiting solution to this issue is a complex multilayered Smart City Management service that allows control over equipment, multiple public services as well as special service for city government internal usage.

Analysis of recent researches and publications. Smart city service is not a novel concept. It has been in use in the 21st century, while the general concept of urban governance has been around since the foundation of the first cities [1, 2]. Prominent research areas in the field of digital urban governance are general concept of smart city services, big data and AI application for smart city service, smart grid and smart waste management solutions etc [3-5]. Apart from general service software architecture, a great deal of attention has been directed towards network and communication protocols within smart city components, embedded and smart device integration platforms, while IoT platform concept being culmination of the electronics equipment integration in existing city management services [6-8]. Some of the research work in the field is aimed toward research and development of special roadmap for future Smart city service implementation [9]. The presented work to some degree is bult upon exiting research efforts, while aimed towards presenting a larger scale more global view on how Smart City Management should be implemented and what software system architecture can be.

Purpose. The purpose of the research work is to present a smart city management system that takes into account modern city governance requirements, consist of both low-level hardware connectors, as well as middleware layer and end-user application, while being generalized and ready for implementation in any given city.

Methods. Data is the main component of any given software management service. Smart city services are based on both hardware and software components. Servies that any city can provide are not limited just to external web portal or digital documentation management sub-services. Most commonly used software applications, digital services and technological devices in Smart City digital service suit are grouped and presented in Figure 1.

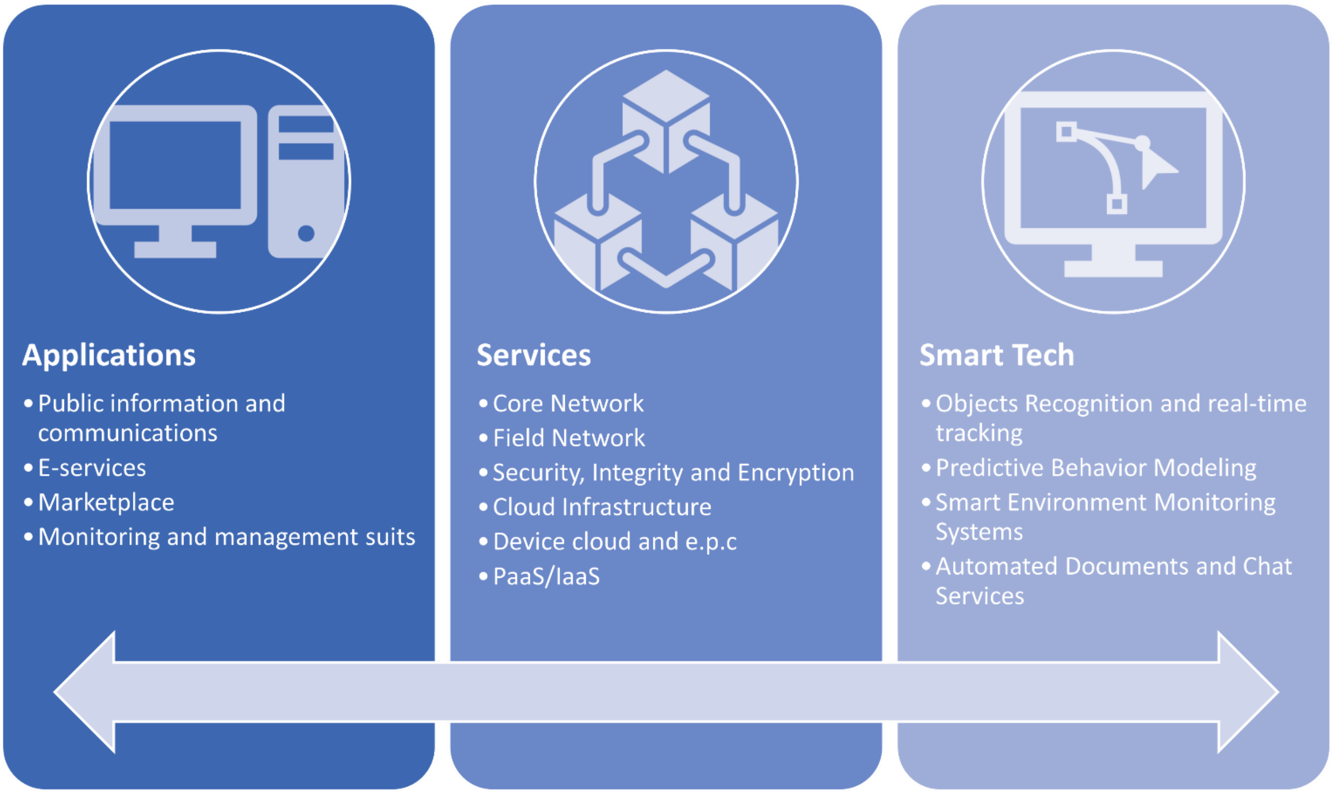

Fig.1. Common Applications, Services and Smart Tech. used in Smart City [10-12]

Smart city Management service consists of many components (Table 1). Each individual component has major systems that enable it function in the service. Systems can be classified as software; in turn each software system requires a list of control parameters and key data types for it to function. The fourth column denotes individual and specific use case scenarios for each system.

Results. One of the key parts of Smart city service suit is IoT middleware platform. The generalized software architecture of IoT platform is presented in Figure 2. This platform follows vertical layers paradigm, services at the bottom are directly connected to individual electronics devices, while those at the top layer can connected and communicates with software service (webs application, web servers and applications data bases among others). The platform is broken down into three core layers, two of them are responsible for external communication and the middle layer is responsible for platform management and event response system. Middleware platform can be connected, and it can exchange data with two types of large-scale systems – endpoint electronics devices and digital services applications suit.

1. Components and Systems for Smart City Management Service*

Component	Systems	Data/Parameters	Use Cases
City	Smart meters Streetlights Waste management Public transport Traffic management Public health	Real time monitoring Emergency Notifications Documentation	City control and maintenance
Hardware	Smart Sensors Monitoring and recording devices Embedded systems Industrial devices	Signals Numerical Logs Commands/Tasks	End-point device network
Middleware and Tech. Platforms	Distributed Sensors network General Services Platform End-point connectors services	Table data (SQL) Object data (NoSQL) Queries RealTime API connections/comms	Software/Firmware platform for communications and layers connections
Communications and Data	Wired/Wireless Smart Grid Gateway Data and protocols	IP addresses Data packets Segments Connection Status Message	Endpoint-to Platform-to Application connection and data transfer
Endpoint (client) applications	Energy Management and streets automation Traffic and emergency management	Realtime data Application Data Communication Data API data	Visualization GDPR Billing and taxes management

* prepared based on author work and public research data [1, 13-15]

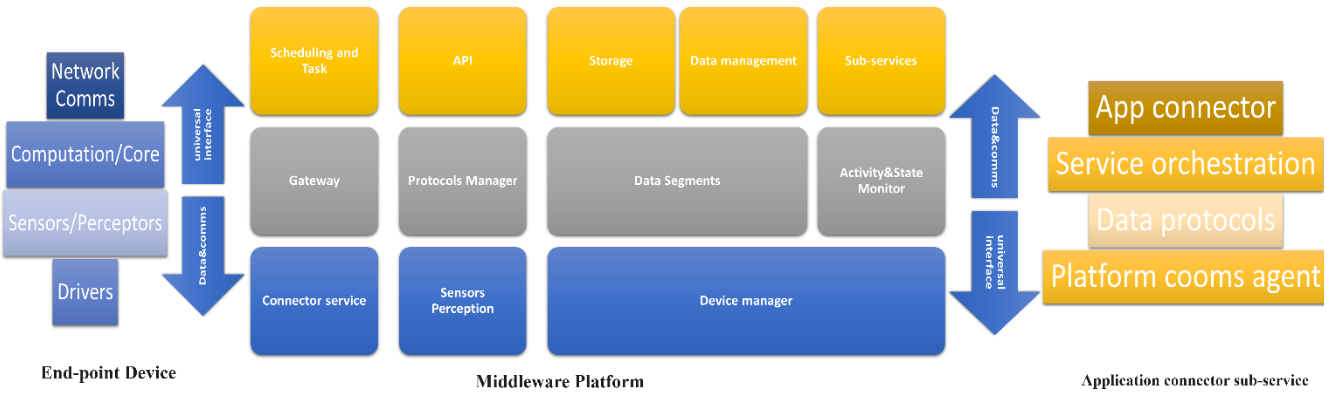

Fig.2. Smart City IoT Middleware Platform

A more detailed IoT middleware platform breakdown is in Table 2. The platform is broken down into seven layers, each individual layer has its own unique systems and components. An important aspect of this architecture is that each layer is connected and there are special communication points that allow data and signals transfers, as well as connection to outer services and systems.

2. IoT Middleware System - embedded and device system layers*

Layer from lower to upper	**Systems**	**Components**
1. Endpoint device	Sensor Actuator Router/Network Device Singal Converter	Power supply Device memory Hardware Data
2. Hardware abstraction	Driver Firmware Kernel Basic notification/indication	Communication Protocol Connectivity Low-level code Local address
3. Core services	Device Configurator Network Configurator Device Authentication (secure) Communication Optimization	(local) Network Data segments Comms Protocols Device (cluster) address
4. Main application services	Protocols Event manager Events System Adaptation System	Message input/output Control code Listeners
5. Service management	Connectivity Registry Manger Event Listener Data processing Maintenance cluster	Data packets Feedback Data Protocols
6. Web Services	Virtual Machine Main Server Additional Servers	Database(s) Server-level code OS Network layers
7. API and connection	Data Connectors Data en(de)-cryption Input/output transfer Visualization/Graphics Application Communication	API connectivity Communication protocol Data packages

* prepared based on author work [7-10]

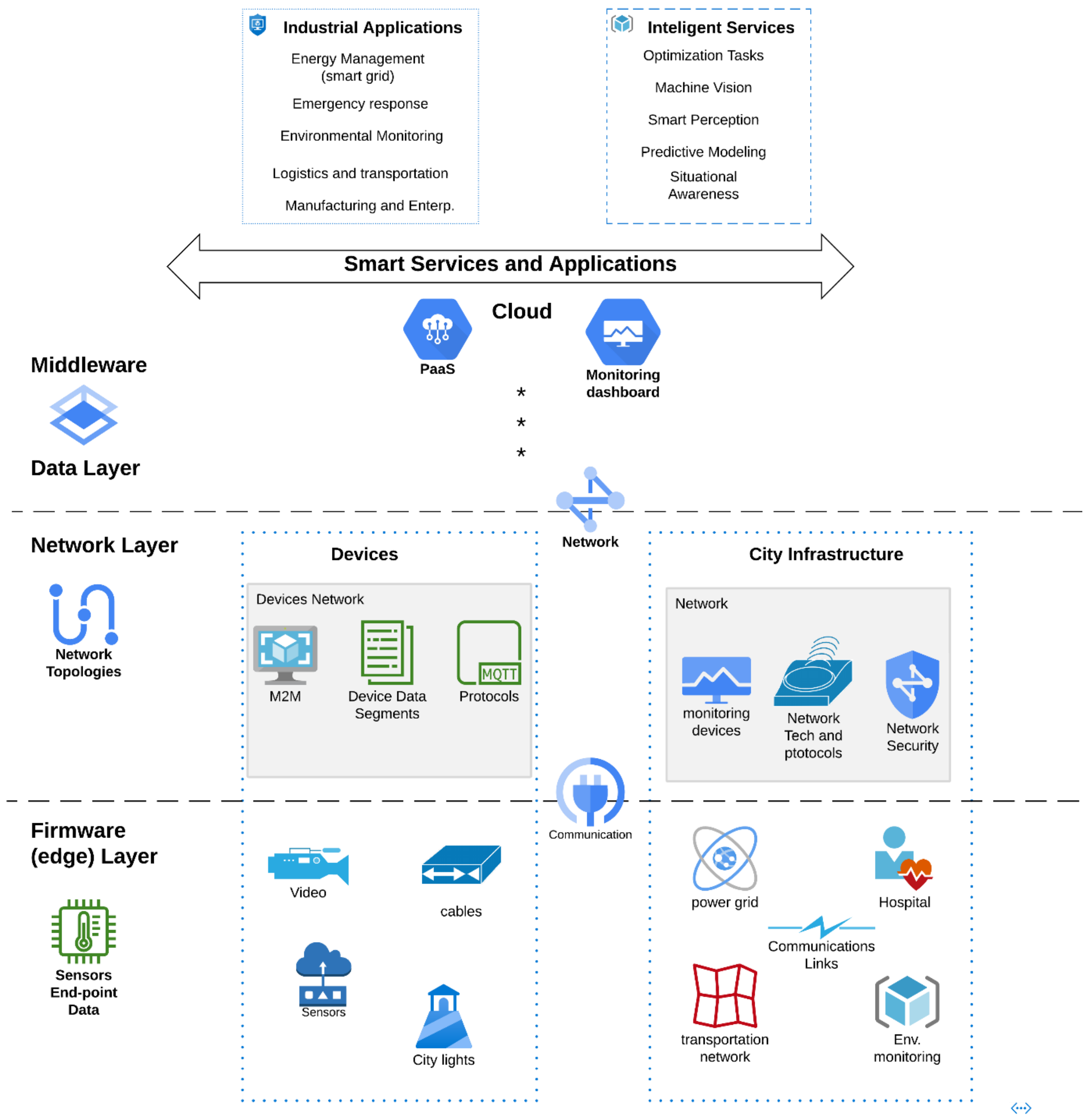

Fig.3. Smart City IoT devices and communications framework (industrial focus)

Smart City IoT Middleware Platform is part of the more global Smart City IoT devices and communications framework (Figure 3). The are four major layers to this framework. The first from the bottom is hardware abstraction, followed by networking and communications layer, the third one is Middleware Platform layer and at the top is application services layer. This framework includes existing city infrastructure and control device systems with focus on embedded systems control and monitoring end-user application. Smart City IoT devices and communications framework are just one of several parts that make Smart City Service. The presented architecture is mainly used for industrial and larger electronics devices that are already in use or can be installed in the city. The applications are used by professional workers and can be further enhanced with the use (and development) of relevant Inteligent services (Figure 3 top-right corner).

3. Smart City IoT implementation roadmap *

Stage	Detailed Steps	Components
I. Research and Planning	1. Analysis of existing solution and state 2. Preliminary analysis and requirements gathering 3. Concept and Roadmap	• Hardware and devices requirements • Resources and power supply management • City plans
II. Platform Architecture and Initial Prototype	1. Use cases and users modeling 2. Devices, data and network modeling 3. Middleware platform design 4. Development of initial software prototype	• System diagrams • UML software modeling • Software Development
III. Data model and Testing	1. API and integration points architecture 2. Platform databases design and development 3. Cloud infrastructure initialization 4. Platform deployment and evaluation	• Data sets • Messaging and communication format • Communication protocols • Connection Protocols • Cloud infrastructure provider
Next Stages	1. Management System Development 2. Sub-systems and services connection 3. System testing and evaluation	• Integration endpoints • API • Automated Testing

* prepared based on author work [7-10]

Smart city IoT middleware system and framework is first of all software solution. Like any software application and platform, it needs to be installed, adapted and tested in real-world server, cloud or any larger scale computational device. The first stage of Smart City service implementation is research and requirement planning phase (Table 3). While it is vital for such complex systems to have complicated architecture, initially platform preliminary software design and prototype development can be considered as better steps, due to time and cost complexity of full system development. As to had been noted before, Smart city service relies on various types of data and data transfer protocols (Stage 3 in Table 3). After the Initial system prototype had been implemented and tested the next step would be integration of existing systems and full-scale system architecture design. As with any complex system Developemnt time and financial requirements should be included for Smart City service Developemnt. Each individual city has their own infrastructure and particularities which must be taken into account for Smart city system planning and design.

Smart City Services System consists of several layers and larger components (Figure 4). While Middleware platform and embedded device system are main components, they are not part of end-user applications. The main part of presented smart city management systems is Smart City Managment platform, which consists of three key layers – Core Services, Mangement services Hub and client Applications. Each sublayer has data access and communication points (via API) and authentication check modules.

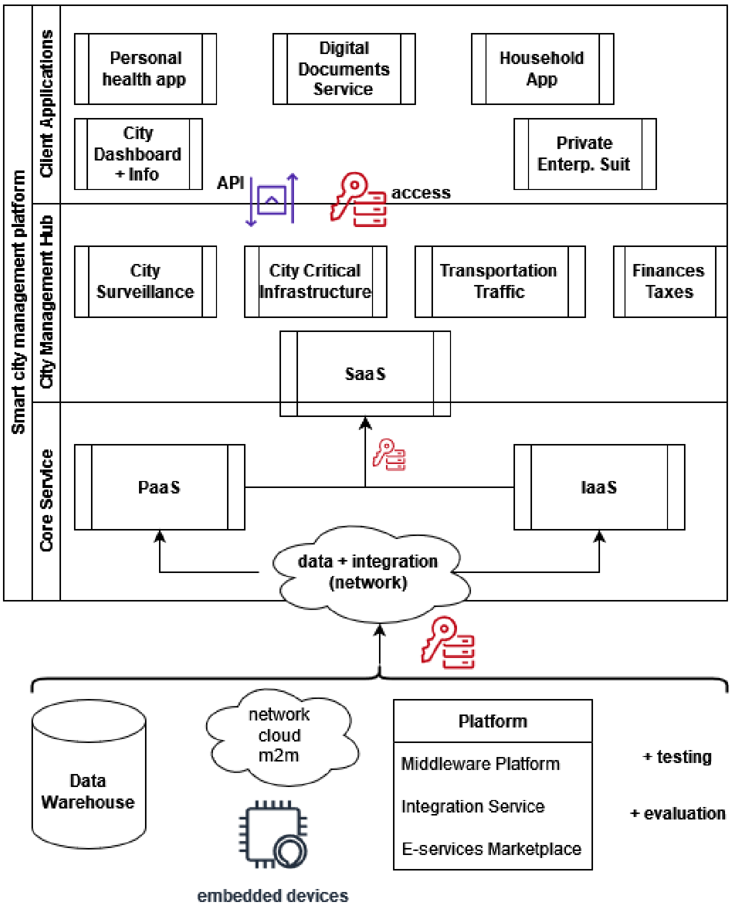

Fig.4. Smart City Services System Architecture

Discussion. The presented Smart City IoT implementation roadmap and Smart City Services System Architecture opens the next step for generalized Smart City Digital service suit. Without a doubt the presented model needs to be verified and tested on several types of smart city platforms. The key issues that can be outlined in context of

Smart City service are its scale, number of underlying software abstraction layers, different architecture of embed systems and IoT platforms as well as large portion of independent end-user applications. Besides being one of the most critical software systems, the issue of security and authentication needs to be included in software architecture. From another point of view, constant power supply (or availability of secondary reserve power supply) availability and 24/7 complete sub-services accessibility are critical requirements for any Smart City service system. The suitability and ecology components can be included in future, to determine the energy consumption of smart city software and hardware systems as well as harmful emissions from servers and other hardware installations.

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СИСТЕМА УПРАВЛІННЯ РОЗУМНИМ МІСТОМ З ВИКОРИСТАННЯМ МІКРО-СЕРВІСІВ ТА СИСТЕМ НА ОСНОВІ ІНТЕРНЕТУ РЕЧЕЙ

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Анотація. *Управління містом, без сумніву, є дуже складною діяльністю. Місто складається не лише з людей та будівель, тут є транспортна та дорожня інфраструктура, дорожнє покриття, критична інфраструктура, медичні заклади, промислові підприємства та багато іншого. Орім того, міська рада надає широкий спектр послуг населенню. Серед них такі як: охорона здоров'я, соціальне забезпечення, економічне та фінансове забезпечення, забезпечення робочими місцями, управління нерухомістю тощо. Для цифрового управління містом використовуються інформаційні системи управління та веб-сервіси, а для управління обладнанням та спостереження використовуються різні вбудовані системи управління. Будучи дуже складною та багаторівневою системою, рішення Smart City Managment пропонує платформу, яка містить основні послуги як для громадськості, так і для технологічних аспектів міського управління. Результати, представлені у статті, ґрунтуються на дослідженнях існуючих програмних, апаратних та проміжних платформ використані для побудови системи розумного міста. Основна увага приділяється платформі проміжного програмного забезпечення, оскільки вона слугує середовищем, яке може об'єднувати існуючі програмні та апаратні рішення. У загальному контексті в системі управління розумним містом всі основні компоненти розбиваються на формат мікросервісів (на рівні розподіленого сервісу великих підприємств). Представлена модель управління, яка складається з низки програмних продуктів, була розбита на кілька рівнів абстракції програмної архітектури: від апаратного забезпечення до додатків кінцевого користувача. У результаті було презентовано дорожню карту впровадження послуг розумного міста, яка включає три етапи. Використовуючи платформу Middleware та моделі Web-сервісів, послуги Smart City Managment можуть бути впроваджені у будь-якому конкретному місті на стадії створення прототипу для подальшої оцінки та впровадження повної версії.*

Ключові слова: ***інтернет речей, штучний інтелект, розумне місто, дизайн програмного забезпечення, управління містом, вбудовані системи***