Comparative Analysis of Smart City Platforms

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Abstract

The concept of transforming cities into smart ones is gaining intensive development in the world and in Ukraine. In order to achieve the status of "smart" city it should meet the criteria regulated by international standards. The objective of the paper is to carry out comparative analysis of the existing platforms of smart cities, their main functionality, areas of application, which will become the basis for the development of requirements for information technology platform for Ukrainian smart cities.

Keywords

Platform, smart city, characteristics, pairwise comparisons

1. Introduction

In order to achieve the development and status of the smart city, various information technology platforms are being developed, the requirements for them are formulated by municipality.

The cities of Ukraine consider this problem to be somewhat simplified and consider the city to be smart if it meets at least the following conditions:

- Achievement of sustainable development in economic, social and environmental spheres.
- Economical use of natural resources.
- Citizens participation in city management.
- City infrastructure uses information technologies for the improvement of the residents living conditions.

2. Related Works

Michael Massoth, Rania El-Gazzar believe that smart decision-making is based on the aggregates of data, considering several application areas of smart cities. Information systems play an important role in the development of smart cities. The authors note that the data can be combined with historical data or other open data from various sources being the basis for decision-making [1].

Michael Massoth offers new approach for mobile online authentication of citizens to access electronic government services based on different trust levels. The innovation is the use of Near Field Communication (NFC), which is supported by Android smartphone as an ubiquitous NFC card reader. The proposed approach implements the possibility for citizens to authenticate both from mobile and stationary devices [2].

Simon Joss argues that the conceptual presentation of the "smart city is based on the application of digital technological systems for urban infrastructure and management processes, implies the return to more modernistic, rational tradition of planning, focused on digital technology as standardization of the

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decision-making process; suggests to turn back from urban spontaneity, focusing on economic growth due to digital technological innovation [3].

In the paper "Future smart cities: requirements, emerging technologies, applications, challenges, and future aspects" smart cities are considered as the means of meeting the constantly growing needs of citizens using information and communication technologies. According to the authors opinion, the creation of sustainable, intelligent space in the cities of the world, which are constantly expanding, is being tested all over the world. They have carried out extensive investigations in order to identify and test the latest technological achievements, including deep learning (DL), machine learning (ML), Internet of Things (IoT), mobile computing, Big Data, blockchain, the sixth generation networks (6G), WiFi-7, industry 5.0, robotic systems, heating, ventilation and air conditioning (HVAC), digital forensics, industrial control systems, connected and automated vehicles (CAV), electric vehicles, food processing, flying cars, backup storage, in case of disaster, and vital cybersecurity integration in order to protect users problems [4].

3. Main characteristics of smart city platforms

In terms of platforms, smart cities have a number of important components, such as connection to IoT, various sensor communication devices, Big Data analysis, clouds and security, as well as blockchain and artificial intelligence. Areas of application should include transport, power engineering, environment, city administration and security (see Figure 1).

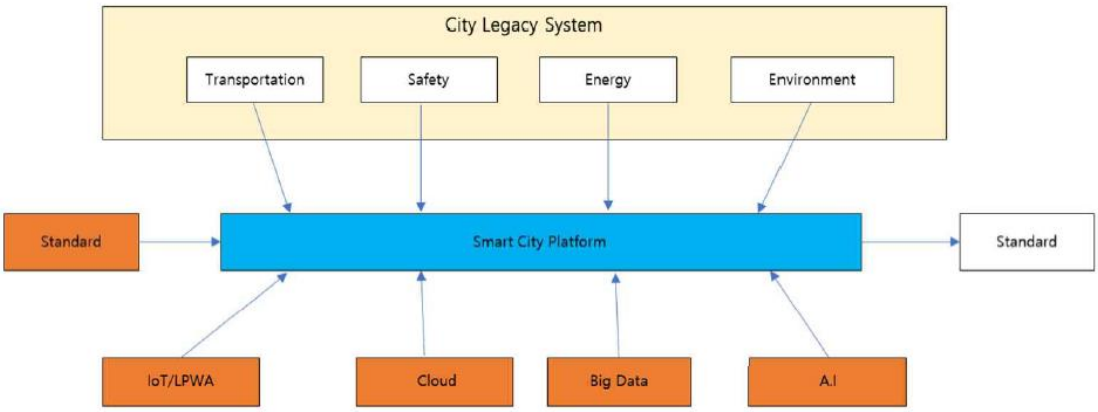

Figure 1: Components of the Smart City structure

Smart city platforms should satisfy all paradigms, such as shared economy, public partnership, business model and data management [5].

Three smart city platforms were considered for further comparison.

3.1. Platform oneM2M

OneM2M platform created in July 2012 in order to develop IoT service platform standard and has become the international standard service platform established by 226 companies, including mobile operators and decision making companies.

The main service areas are smart homes, smart cars, smart networks and healthcare. Common platforms provide standardized service APIs that connect different heterogeneous IoT devices.

OneM2M architecture has the structure of applications, common services and network services (Figure 2), and CSE (common service organization - provides a set of "service functions" which are common for M2M environment) includes 12 CSFs (common service functions):

- registration;
- openness;
- security;

- group management;
- data management and storage;
- subscription and notifications;
- device control;
- management of applications and services;
- communication management;
- exposition of network services;
- location detection;
- calculating and accounting of services.

They are exposed externally by means of reference points for service provision (reference points of one or more interfaces - Mca, Mcn, Mcc and Mcc' (between 2 service providers)) [6].

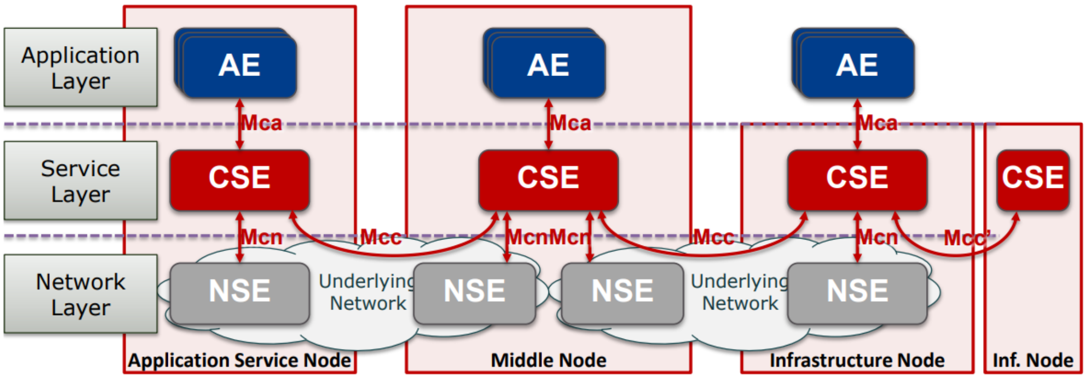

Figure 2: Architecture of oneM2M platform

OneM2M platform operates due to API using REST architecture (in Fig. 3).

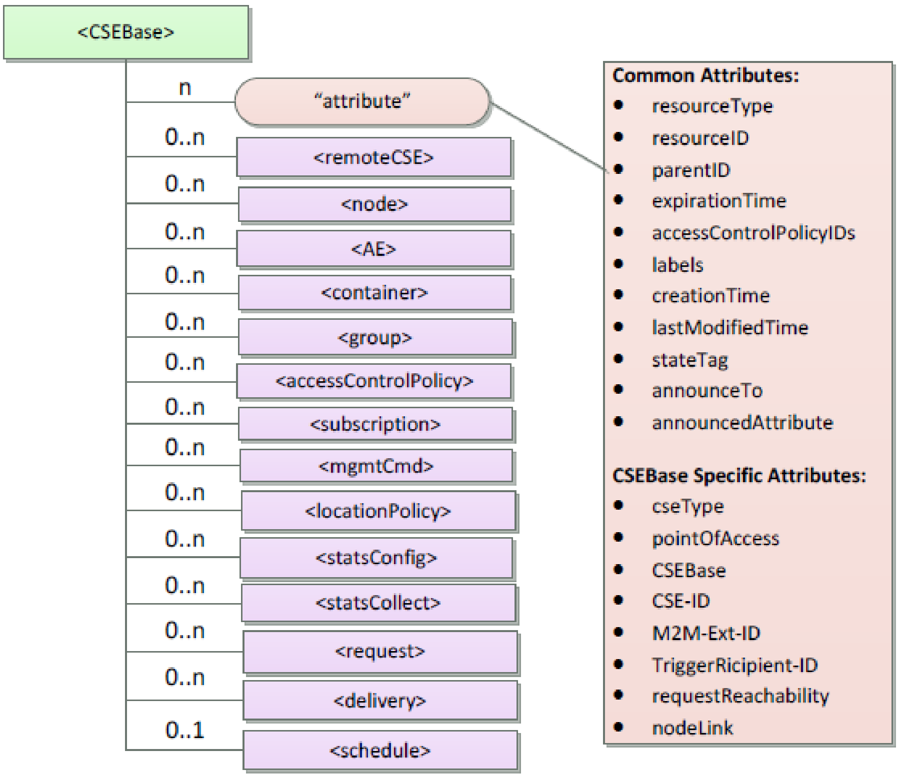

Figure 3: OneM2M REST resource structure

OneM2M provides the structure of resources for sensors to obtain their information, supplies semantic information about the content of the resource and the functionalities that use it (in Fig. 4).

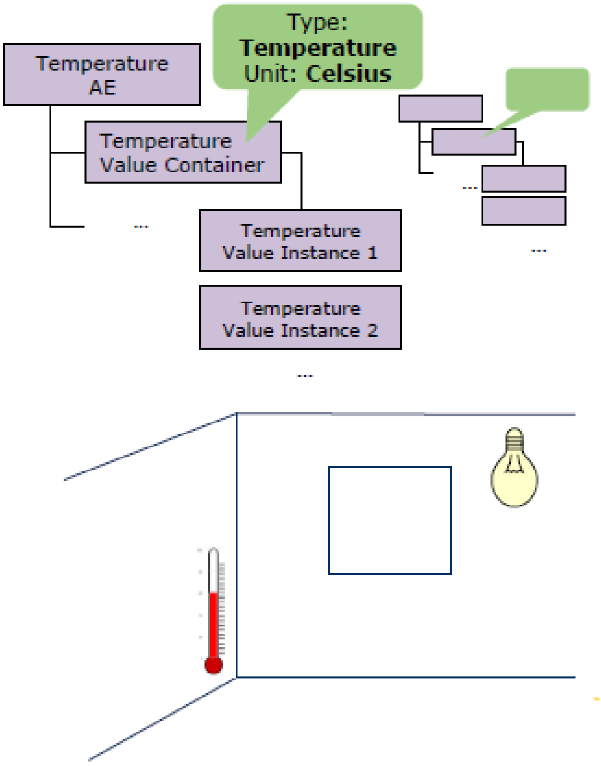

Figure 4: Platform application of in smart homes (automatic configuration for each change of available sensors)

Functionality provided or extended due to semantics includes:

- queries/openings based on semantic descriptions;
- analytics support;
- support for creating associations (for example, activation of IoT scenarios).

Software with information use is able:

- to specify what information is required and to receive notifications in case of relevant changes;
- to define clearly the syntax and semantics of information, so programs can decide whether they can process it, which module is required for processing, etc.

At present oneM2M is the internal demonstration project used in Busan, Daegu and Goyan (South Korea) to provide services such as transport, healthcare and environment.

3.2. FIWARE platform

FIWARE is an open source platform that stands out for the standardization of smart city platforms in Europe, provides various components and supplies NGSI and context brokers, the next-generation interface based on open API. The Japanese electric corporation NEC, which is used at present in the countries around the world, is also creating its own security platform using FIWARE open source [7].

The general idea of the platform is data collection from various sensors installed throughout the city. These sensors should collect data such as temperature, humidity and concentration of fine particles (PM2.5 and PM10).

The obtained data provide easy-to-use information panel, their visualization by means of geographical map, table and various diagrams [8]. Selected data are combined with external data (e.g. regional weather data) in order to create predictive model regarding solid particles concentration [9].

The essence is that some of these sensors are installed at predetermined points that have been proposed by the environmental department. In order to have necessary power supply, you should choose traffic lights or light poles located close to these points. On the other hand, certain sensors should be installed on public transport vehicles (buses and trams). These mobile sensors should also report their current position along with other data. In addition, data transfer should be carried out in such a way that every 200 meters the indicators updated values are received.

FIWARE platform is grouped into seven main parts, called “common tools” [10]. Each of them represents specific aspect of FIWARE services and provides one or more components, along with reference implementations supporting the specified APIs. In addition, there are so-called “domain-specific activators” that provide components for certain domains, such as health, energy, etc. Common tools are listed in Table 1.

Table 1
Common tools of FIWARE platform

No	Tool denomination	Tool intention
1	Data/context management	Contains all the components required for storing, accessing, processing and analyzing data as part of smart application
2	Enabling Internet of Things (IoT) services	Contains all the components required to configure sensor networks and to route sensor data to other tools
3	Expanded user web interface	Components for developing user interfaces, including geographic information and interactive 3D diagrams
4	Security	Components for adding, defining, and ensuring declarative security
5	Advanced middleware and interfaces to network and devices	
6	Applications/services and data delivery	Components and tools for data visualization, simple generation and distribution of services and data in the app store
7	Cloud hosting	Components and tools aimed at providing and managing FIWARE services through cloud infrastructure

FIWARE uses a wide variety of different programming languages (C++, Java, Python, NodeJS, ...) and environments in order to develop their reference implementations. FIWARE community provides docker images for each component simplifying operation with different runtime requirements.

The basic components of FIWARE platform implementation include:

- Context broker – Orion is persistent data storage with REST API. In fact, it uses MongoDB sample as its internal data storage and offers RESTful access to it through Open Mobile Alliance Service Interface (NGSI) protocol. Since NoSQL document storage is basic data storage, Orion doesn't use database schemas as well and makes it possible to create any type of object. It supports simple URL-based query language which also provides projections and pagination. Thus, in cases where longer list for subset of attributes only is required, this can be easily achieved [11].

- Management of server devices – IDAS. Provides REST end point with API required for the register of donors and operation with their data.
- Storage of time series data – Cygnus. This component is essentially Apache Flume extension used to store updates in persistent storage. It listens to input data, which are then forwarded – according to internal configuration – to one or more data receivers [12]. Other possible data receivers include MongoDB, HDFS, and PostgreSQL.

In order to store sensors values constantly for a long period time, Cygnus creates the subscription with context broker. This ensures that every time when specific property of specific type of object changes (for example, the property of bus-type objects location), Cygnus receives this information and sends it to the storage (in Fig. 5).

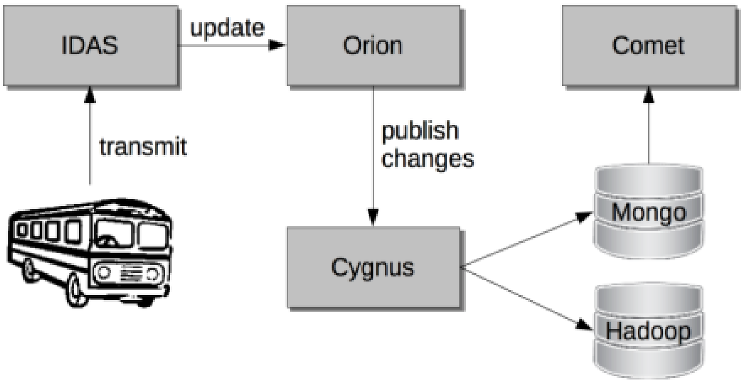

Figure 5: Sensors data flow in FIWARE

Comet is the component providing RESTful access to historical data receiver of Short Term Historic (STH) [13]. It provides API for reading historical data produced by the component chain described above, but still supports only MongoDB data receivers.

FIWARE's standard security infrastructure is based on OAuth2 [14]. IdM identity management is a central component of FIWARE's security architecture. The second important security component in FIWARE security architecture is Policy Decision Point (PDP). The set of security components is supplemented by policy enforcement point (PEP). PEP is very simple proxy server located in front of the service which must be limited and acts as actual resource server according to OAuth2. The actual authentication and authorization flow is shown in Figure 6.

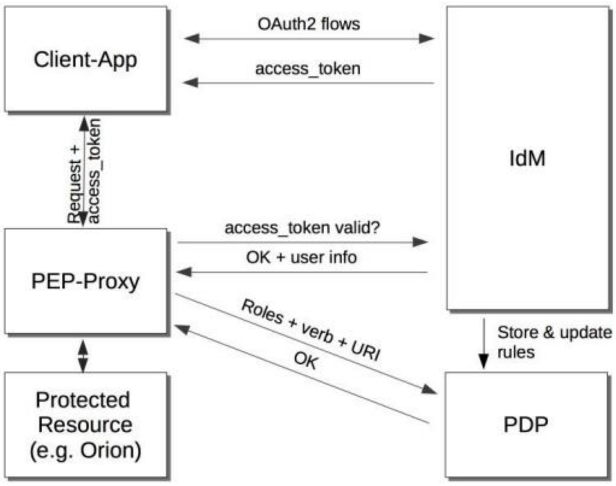

Figure 6: Main authorization flow

In order to visualize data in the form of tables, graphs, FIWARE platform provides Wirecloud component [15], which is the web interface which makes it possible to combine small blocks called widgets or operators into dashboards by very intuitive and easy-to-use way. As it is shown in Figure 7, widgets and operators can be connected by means of drag-and-drop editor.

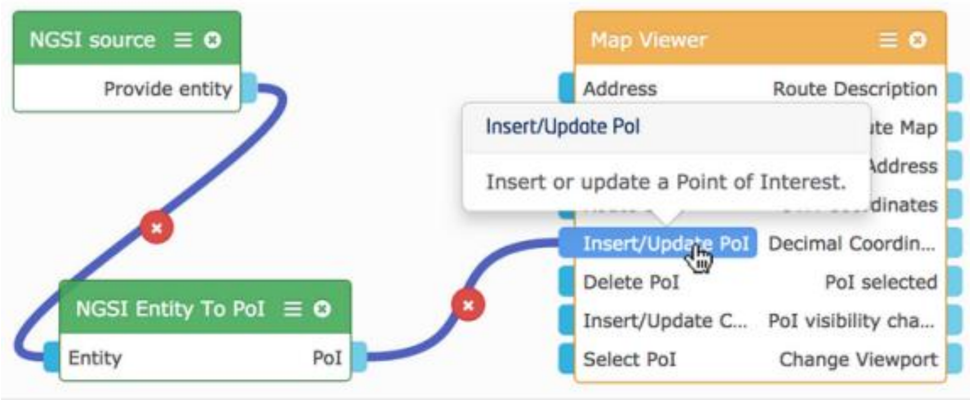

Figure 7: Connecting component by dragging using editor

The interaction of all components of this platform is shown in Figure 8.

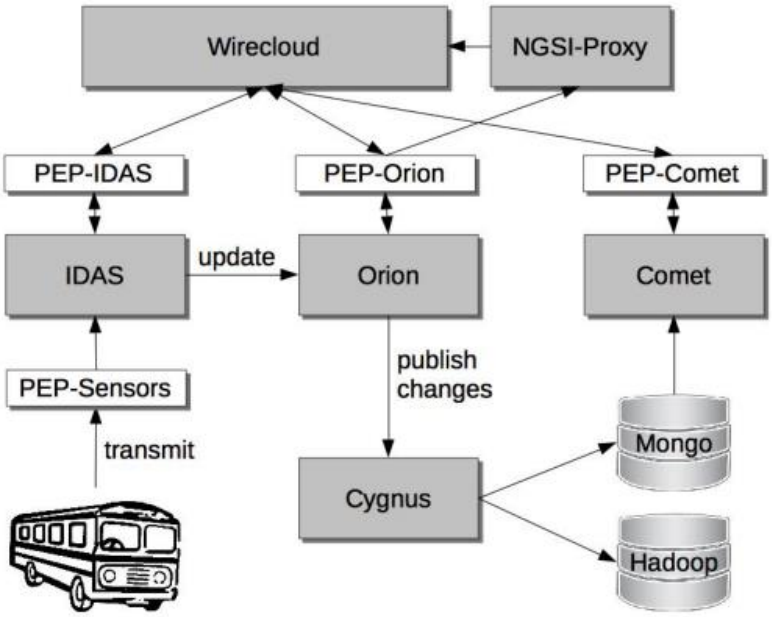

Figure 8: General architecture of FIWARE platform

Therefore, FIWARE creates a new generation of intelligent applications using large-scale "contextual information" in real time. The efforts are focused on promoting compatibility and free flow of data within and between cities, cooperation between cities in order to adopt common standards which can create the landscape of diverse but interacting Smart City solutions. FIWARE contributes to the creation of significant market where the developers can start investing, and cities provide the basis for data economy development [7].

3.3. Cisco Kinetic for Cities platform

The Cisco platform provides the opportunity to collect data from various types of devices and sensors in response to city requirements, to analyze cross-domains and APIs as open platforms, as well as to manage security keys [7].

The main characteristics of the platform include:

- end-to-end solution from sensors, peripheral and basic networks to programs, dashboards and analytics;
- sensor technology and providers supporting several domains;
- open data and API;
- support for the requirements regarding data privacy and sovereignty;
- enhanced security and role-based access control;
- supports people and processes – not only technology;
- long-term platform with the possibility of cost-effective scaling and expansion over time (digital transformation of the smart city) [16].

The platform includes API for such domains of urban services as outdoor lighting, parking, urban mobility, crowd, traffic, environment, security, waste management [17].

Cisco Company has developed a framework in order to assist the cities in digitization (in Fig. 9).

Figure 9: Solution structure from Cisco Company

Cisco Kinetic for Cities platform is delivered as the cloud service or local deployment model. The platform collects data from sensors using secure network connection – both wired and wireless – to transmit these data to the cloud. This platform uses secure cloud technologies in order to provide storage, virtualization, adaptability and analytics making it possible to increase the data value and their transmission speed at the same time reducing costs. Its architecture is shown in Figure 10.

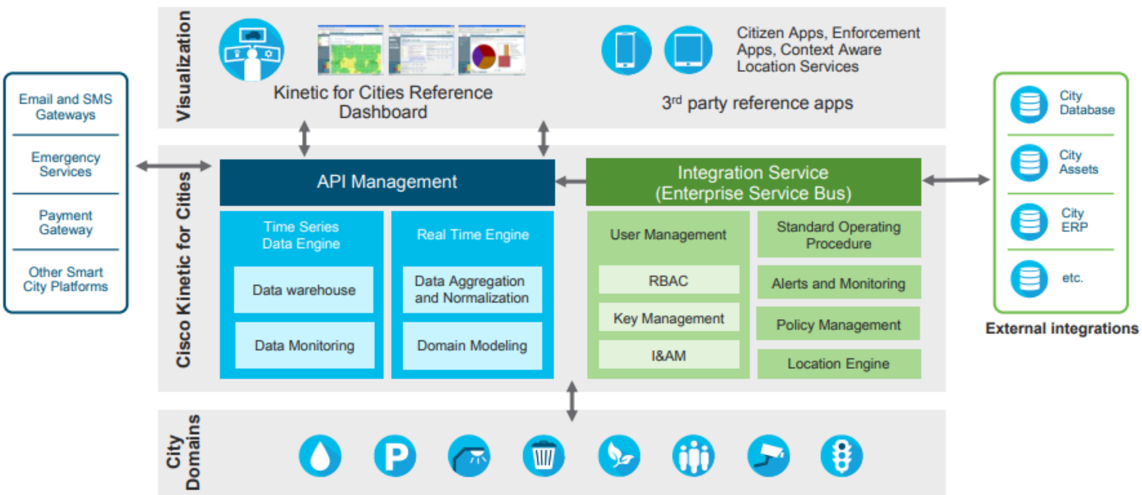

Figure 10: Architecture of Cisco Kinetic for Cities platform

The platform provides access to city-wide data, making it possible to use them by devices, applications and services in various domains for triggering notifications or actions based on criteria set by your community. This functionality is derived from the ability to combine data from different sources, regardless of their individual protocols, and safely transfer them and use them for operation of geoinformation systems for many important purposes throughout the city [16]. The network topology is shown in Figure 11.

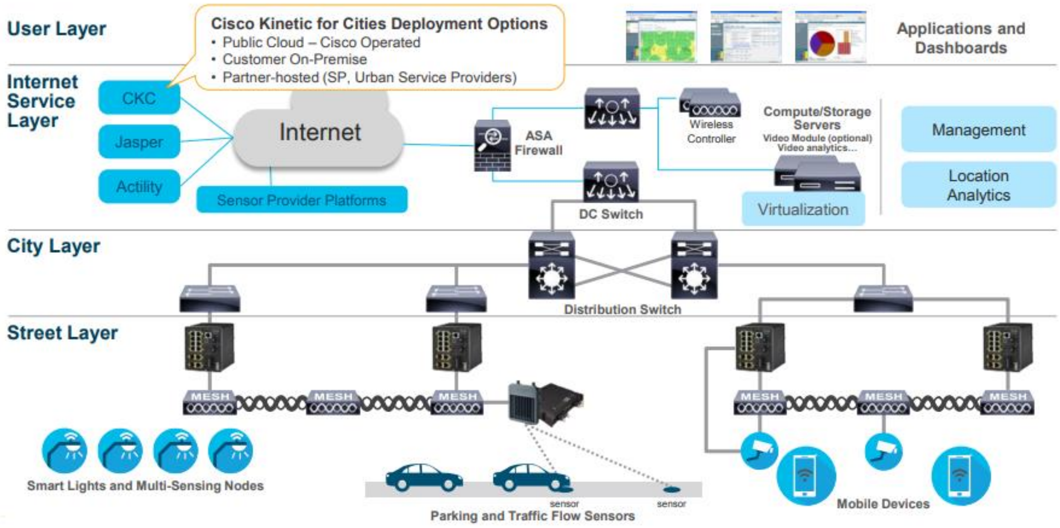

Figure 11: Network topology for Cisco Kinetic for Cities platform

In general, the platform provides convenient interface for the city operator, where he can see the dashboard with up-to-date data and graphs, as well as adjust policies according to the city requirements (in Fig. 12).

Figure 12: Results of Cisco Kinetic for Cities platform in the form of dashboard

Based on Cisco Kinetic for Cities platform, Cisco Company also provides platforms and solutions for Busan Smart City and Songdo Smart City in Korea.

4. Comparative analysis of information technology platforms by Saati method

In this paper, we have chosen the criteria “functions”, “tools”, “characteristics”, “implementation” for comparative analysis. The carried out expert assessment based on these criteria makes it possible to build the hierarchy for choosing the best implementation of the Smart City platform (Fig. 13).

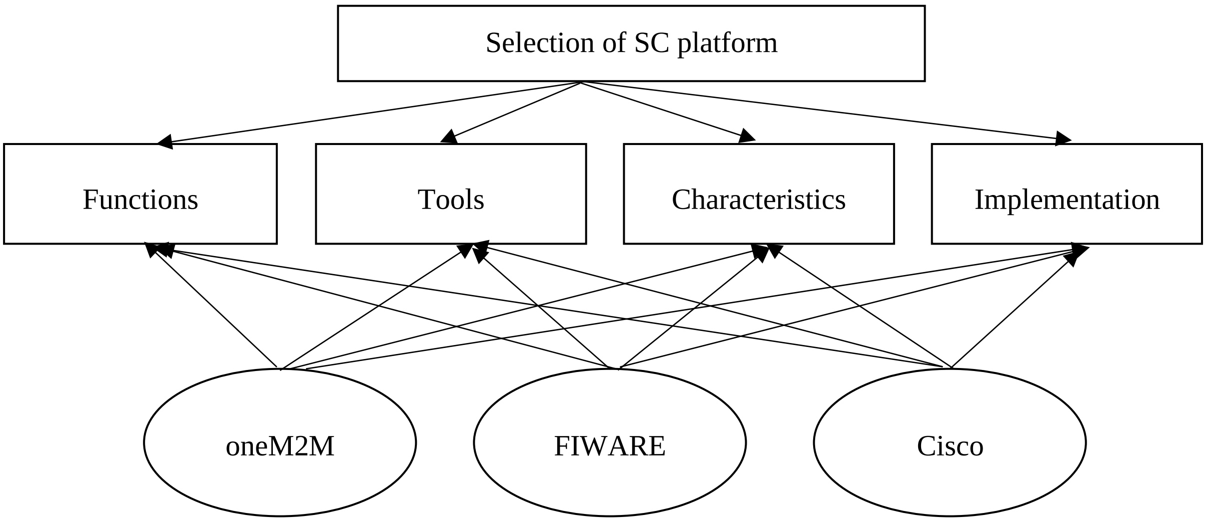

Figure 13: Hierarchy for solving the problem of choosing the best implementation of the Smart City platform

The results of expert assessment on 10-point scale are represented in Table 2.

Table 2
Results of expert assessment of SC platforms

Platform	Functions	Tools	Characteristics	Implementation
oneM2M	8	3	4	3
FIWARE	5	3	5	1
Cisco	4	2	8	2

Based on the results of expert assessment for the investigated Smart City platforms, let us determine the best platform by means of Saati method.

Normalized matrix of pairwise comparisons of criteria with regard to the goal is shown in Table 3.

Table 3
Normalized matrix of pairwise comparisons of criteria with regard to the goal

Selection of SC platform	Functions	Tools	Characteristics	Implementation	Local priorities vector	Normalized vector of these priorities
Functions	1	6	2	6	2.913	0.537
Tools	1/6	1	1/3	5	0.726	0.134
Characteristics	1/2	3	1	3	1.456	0.269
Implementation	1/6	1/5	1/3	1	0.325	0.060
Sum	1.83	10.20	3.67	15.00	5.420	1
$\lambda_{\max}$ = 4.325; CI = 0.08; RI = 0.9; CR = 0.09 < 0.1						

Normalized matrix of pairwise comparisons of alternatives with regard to "Functions" criterion is shown in Table 4.

Table 4
Normalized matrix of pairwise comparisons of alternatives with regard to "Functions" criterion

Functions	oneM2M	FIWARE	Cisco	Local priorities vector	Normalized vector of these priorities
oneM2M	1	5	9	3.557	0.751
FIWARE	1/5	1	3	0.843	0.178
Cisco	1/9	1/3	1	0.333	0.070
Sum	1.31	6.33	13.00	4.734	1
$\lambda_{\max}$ = 3.029; CI = 0.01; RI = 0.58; CR = 0.03 < 0.1					

Normalized matrix of pairwise comparisons of alternatives with regard to "Tools" criterion is presented in Table 5.

Table 5
Normalized matrix of pairwise comparisons of alternatives with regard to "Tools" criterion

Tools	oneM2M	FIWARE	Cisco	Local priorities vector	Normalized vector of these priorities
oneM2M	1	1	6	1.817	0.472
FIWARE	1	1	5	1.710	0.444
Cisco	1/6	1/5	1	0.322	0.084
Sum	2.17	2.20	12.00	3.849	1
$\lambda_{\max}$ = 3.004; CI = 0.002; RI = 0.58; CR = 0.003 < 0.1					

Normalized matrix of pairwise comparisons of alternatives with regard to "Characteristics" criterion is presented in Table 6.

Table 6
Normalized matrix of pairwise comparisons of alternatives with regard to "Characteristics" criterion

Characteristics	oneM2M	FIWARE	Cisco	Local priorities vector	Normalized vector of these priorities
oneM2M	1	1/3	1/9	0.333	0.066
FIWARE	3	1	1/7	0.754	0.149
Cisco	9	7	1	3.979	0.785
Sum	13.00	8.33	1.25	5.066	1
$\lambda_{\max}$ = 3.080; CI = 0.04; RI = 0.58; CR = 0.07 < 0.1					

Normalized matrix of pairwise comparisons of alternatives with regard to "Implementation" criterion is presented in Table 7.

Table 7
Normalized matrix of pairwise comparisons of alternatives with regard to “Implementation” criterion

Implementation	oneM2M	FIWARE	Cisco	Local priorities vector	Normalized vector of these priorities
oneM2M	1	9	7	3.979	0.785
FIWARE	1/9	1	1/3	0.333	0.066
Cisco	1/7	3	1	0.754	0.149
Sum	1.25	13.00	8.33	5.066	1
$\lambda_{\max}$ = 3.080; CI = 0.04; RI = 0.58; CR = 0.07 < 0.1					

$\mathrm{CI_{alt}}$ = 0.021; $\mathrm{CI_{hierarchy}}$ = 0.1; $\mathrm{RI_{hierarchy}}$ = 1.48; $\mathrm{CR_{hierarchy}}$ = 0.067 < 0.1.

Let's find the significance vector of global priorities of alternatives (1).

$$\begin{pmatrix} 0.751 & 0.472 & 0.066 & 0.785 \\ 0.178 & 0.444 & 0.149 & 0.066 \\ 0.070 & 0.084 & 0.785 & 0.149 \end{pmatrix} \times \begin{pmatrix} 0.537 \\ 0.134 \\ 0.269 \\ 0.060 \end{pmatrix} = \begin{pmatrix} 0.532 \\ 0.199 \\ 0.269 \end{pmatrix} \tag{1}$$

As conclusion of the investigation, we have got that oneM2M platform is the winner with 53.20% advantage, with significantly weaker Cisco (26.90%) and the FIWARE platform has the lowest mark (19.90%).

5. Conclusions

The platforms provide almost the same functionality, but such characteristics as user interface (choice of the graph construction type, data filter for tabulation), speed of Big Data processing (especially in megacities), fault tolerance, availability of backup power supply in the city sensor system, and a number of other characteristics should be tested directly at the stage of smart elements implementation in the specific city. After that, it will be possible to carry out conditional division of platforms according to the criteria (for example, by city area and population) and then there will be no problems for new cities to implement them, if they meet all the requirements of the city, citizens and local authorities. Approbation is the mandatory element of the investigation concerning the smart city platforms effectiveness, because the platform effectiveness is obviously not the same for different cities from different countries.

At present, Ukraine has chosen the direction of digitization and smart elements are being actively implemented both at the city and state levels.

It is should be noted that at present there are only platforms that manage the specific city. In order to solve these problems, each country should build standardized data formats rather than independent platforms, and due to this fact, it is necessary to focus on using data by data center platform which connects platforms between cities and connects common data together in cloud infrastructure.

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