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SMART CITIES AND 5G NETWORKS: AN EMERGING TECHNOLOGICAL AREA?

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Abstract: The term "smart city" has recently become greatly widespread in academic and political discourse. Nevertheless, this is rather a marketing term that unites a number of technological (and other) areas: Internet of Things (IoT), augmented and virtual reality (AR/VR), communication networks. The latest generation of networks is essential for the development of digital ecosystems of smart cities. It has been assumed that the smart city and 5G networks form an emerging technological area. The goal of the work is to study the structure of the development and implementation of new technologies for the urban environment on the sample of 5G-based technologies. For the analysis of new technologies in the selected subject area, a study of patent landscapes and scientometric analysis of the topic field has been conducted. The object of the scientometric analysis is the study of citation patterns. The use of the patent landscape is based on the information systems and databases of patent information developed by patent offices and commercial companies and consists of visualizing the logical connections between various indicators of patent activity, on the one hand, and technological and market trends, on the other. Together, the scientometric and patent landscape show the most promising areas of technological research. The results of the study can be used in further theoretical and applied research, in the formation of government policy in research and development, as well as in decision-making in the field of urban management.

Keywords: urban geography; 5G; 6G; scientometric analysis; patent landscape

Introduction

The majority of Europe's population (about 74%) lives in cities, and in North and South America, the urban population share exceeds 80% (United Nations, Department of Economic and Social Affairs, Population Division, 2019). Asian and African countries are still lagging in the share of the urban population, but in the future, 80% of the world's urban population will live in developing countries (United Nations, Department of Economic and Social Affairs, 2013). Such a rapid pace of urbanization,

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on the one hand, contributes to progress; on the other hand, it poses a serious threat to sustainable development. A city as an object of study attracts the attention of a wide range of social sciences, including economics, sociology, and human geography (Vuković, Jovanović & Djukić, 2012; Vuković, Larionova, Platonov, & Vuković, 2017; Vuković & Wei; 2010). The phenomenon of the post-industrial smart city is at the intersection of social sciences and engineering. Despite the fact that the term has long been at the center of scientific and political discourse, there is no single approach to its definition. An analysis of various definitions of a smart city is beyond the scope of this study; we refer the interested reader to the report of the International Telecommunication Unit (ITU Telecommunication Standardization Sector [ITU-T], 2015a). We grounded on one of the most widely used definitions (ITU-T, 2015c, p. 3): "A smart and sustainable city (SSC) is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects".

Initially, the smart city was characterized as ubiquitous, i.e., the user can get access to the information through the web, but more importantly, it is accessible at any time, and in any place (mobile) (Jaokar, 2012). Thus, wireless networks play a crucial role in the development of a smart city. Fifth Generation (5G) networks provide entirely new capabilities in this regard. The smart city network architecture is closely related to the development of flexible network nodes based on the Software-Defined Networking (SDN) architecture and network function virtualization (NFV) for optimal processing of the node functions and improving the operational efficiency of the network (ITU-T, 2015b).

The goal of this study is the identification of the research niche that arises from the overlapping of smart city and next-generation wireless networks. We have identified key research trends in this area based on the scientometric analysis. Nevertheless, we understood that developing areas are characterized by increased patent activity rather than a large number of scientific publications. Therefore, the analysis of the patent landscape complements the results of the scientometric study.

Methodology

We used *VOSviewer* for scientometric analysis. It is a computer program that allows you to create, visualize, and analyze network maps built on bibliographic data. *VOSviewer* also provides text mining functionality that can be used to construct and visualize *co-occurrence networks* of important terms extracted from a body of scientific literature (van Eck & Waltman, 2019). *VOSviewer* focuses on the visualization of bibliometric maps. *VOSviewer* functionality is especially useful for displaying large bibliometric maps in a simple, efficient way. It is especially useful for maps containing a moderately large number of items (e.g., at least 100 items) (van Eck & Waltman, 2010, 2014). *VOSviewer*, by default, applies association strength normalization (van Eck & Waltman, 2009). Then, the program uses a mapping technique described in detail by van Eck, Waltman, Dekker, and van den Berg (2010). Finally, *VOSviewer* assigns the network nodes to clusters; the clustering technique is presented in Waltman, van Eck, and Noyons (2010). For the purposes of this study, we mainly used text mining functionality for constructing co-occurrence networks of terms extracted from the metadata.

For the analysis, we used data obtained from *Scopus* (Elsevier B.V., 2019). A query for the keywords *smart cities, smart and sustainable city, SSC, 5g,* and *fifth generation* resulted in 239 documents starting in 2016. In turn, the same query in *Web of Science* (Clarivate, 2019) produced only 141 results, which seems somewhat insufficient for a complete network analysis. Further, in our research we used only

articles, reviews, and conference paper (taking into account that the subject covers publications in computer sciences, conference proceedings are of great importance). As a result, we got a set of 202 documents.

However, without an analysis of the patent landscape, the picture would have been incomplete. We found 331 international patents for the specified period. The analysis of the patent landscape was carried out based on the data from the patent database *Questel Orbit* (QUESTEL SAS, 2019), which combines more than 100 different databases. It is the world's largest patent fund, which contains over 60 million documents from 95 countries and the International Patent Offices. Also, the complete information about related patents (patent family = patent analogs) is available here, including their legal status.

Results and discussion

The analysis array contains 1,842 key phrases. At the first stage, using the thesaurus, we combined synonyms, and also set a threshold of 10 occurrences. As a result, we got a semantic core of 19 key phrases. The results of the network analysis are presented in Figure 1.

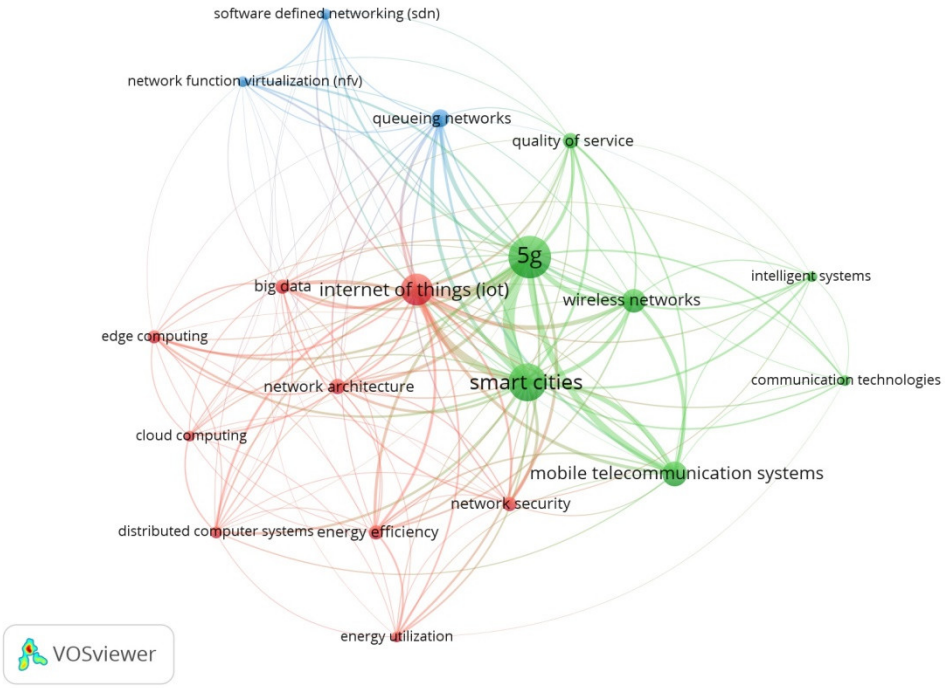

Figure 1. The network of key phrases. Developed by the authors with VOSviewer software.

The terms are distributed among 3 clusters. The largest cluster has formed around the Internet of Things (IoT) and its practical applications in the context of a smart city (Albreem et al., 2018; Poncha,

Abdelhamid, Alturjman, Ever, & Al-Turjman, 2018; Satyakrishna & Sagar, 2018). This finding indirectly confirms our hypothesis that the IoT is to some extent, a "core" term or technological core for a smart city. The term "smart city" itself is more within political and media discourse. From a technological perspective, the IoT is a global infrastructure for the information society that provides the ability for more complex services by connecting (physical and virtual) things to each other based on the existing and developing ICTs (ITU-T, 2012). According to Shi, Sun, Cao, Zhang, and Liu, (2017), big data are also a key technology for a smart city. It is the need for constant access to data and the transfer of large amounts of information that makes the development of fifth-generation wireless networks urgent. Accordingly, future scenarios for the development of IMT include (ITU-T, 2015b):

- *eMBB (enhanced Mobile BroadBand).* Mobile broadband covers human-centric usage scenarios that provide access to multimedia content, services, and data.
- *URLLC (Ultra-reliable and Low-Latency Communication)*. This usage scenario places stringent demands on metrics such as throughput, latency, and availability.
- *mMTC (massive Machine-Type communication).* A large number of connected devices characterize this usage scenario, usually transmitting a relatively small amount of data that is not so sensitive to delay. It is necessary to ensure low cost and long battery life.

The second cluster (7 terms) is built directly around the *smart cities* and *5G* (Rao & Prasad, 2018; Usman, Asghar, Granelli, & Qaraqe, 2018). The third cluster is quite small (3 terms) and stands somewhat apart. It includes technical terms that directly relate to the network infrastructure of a smart city (Khan, Dang, Dörsch, & Peters, 2018; Oproiu, Iordache, Costea, Brezeanu, & Patachia, 2018; Velasco & Ruiz, 2018). Namely, it consists of:

- *SDN*, which is a set of techniques that enables users to directly program, orchestrate, control and manage network resources, which facilitates the design, delivery, and operation of network services in a dynamic and scalable manner (ITU-T, 2014).
- *NFV*, which is a principle of separating network functions from the hardware they run on by using virtual hardware abstraction (ETSI Industry Specification Group, 2018).
- Queueing *networks*, i.e., networks based on the mathematical apparatus of queuing theory (Kleinrock, 1975).

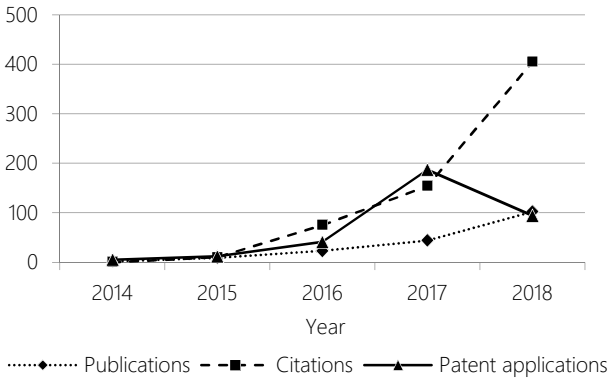

Figure 2. Analysis of the key scientometric indicators. Based on data obtained from *Scopus* by *Elsevier* (Elsevier B.V., 2019) and *Orbit Intelligence* by *Questel* (QUESTEL SAS, 2019).

The link between the second and the third cluster is *quality of service (QoS)* (Karadimce & Marina, 2019). As mentioned above, patent activity in the analyzed area is ahead of the number of publications. We compared the number of patents, publications, and citations over time (Figure 2). However, the graph shows that the peak of patent activity was passed in 2017. It is one of the signs that technology is moving from a growth phase to a maturity phase.

The leaders in the field of patents in this area are China and the USA, and patent activity is also

observed in Europe, India, Korea, Japan, Australia, Canada and Brazil (QUESTEL SAS, 2019). We analyzed only international patents. Some countries (for example, Russia) register patents only in national jurisdictions.

Conclusion

A smart city as an object of research is at the intersection of engineering, computer science, and social sciences. The definition of a smart city was initially associated with ICT infrastructure. Wireless telecommunications play an essential role in the development of vertically integrated urban industries. We used scientometric analysis and the analysis of patent landscapes to determine the structure of this technological field and its development potential. The scientometric analysis revealed three clusters of key phrases built around the terms IoT, smart city and 5g, and network technologies (SDN, NFV, queuing networks). The peak of patent activity, as well as the investment in R&D, has already been passed, although there are still more patents than scientific publications. It indicates the transition of technology from the growth phase to the maturity phase (growth retardation) when the first signs of demand saturation appear. The USA and China are the leaders in the intellectual property market, with their organizations such as *Samsung Electronics* and *Huawei*. The investment trend confirms the accuracy of determining the phase of the technology life cycle. Of course, wireless networks will always play an essential role in the context of smart cities. However, large-scale investments in 5G research and development for smart cities seem risky due to the saturated competitive market.

The next generation of mobile systems is on the verge. Research on the conceptualization of technologies for the next generation of mobile communications systems (sixth generation, 6G) is at an early stage around the world (Giordani, Polese, Mezzavilla, Rangan, & Zorzi, 2019). However, there is already some research groundwork related to the understanding of both targeted applications and the most promising candidate technologies. It is expected that 6G networks will support even higher densities of connected devices, mobile AR/VR services, holographic telecasts, smart city and remote medicine applications, as well as a variety of autonomous and industrial services. For these purposes, the transmission will be applied at increasingly higher frequencies (for example, millimeter waves, in the terahertz wavelength range and with the use of visible light), as well as full-duplex communication, using advanced techniques for assessing the wireless channel and tools for the positioning of devices. The architecture of 6G systems can evolve in the direction of abandoning the concept of a cell while integrating even more closely radio technologies operating in different frequency ranges, as well as taking into account vertical measurement. Support for virtualization tools for network functions and artificial intelligence technologies (for example, machine learning techniques) will empower even higher flexibility of 6G networks.

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