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ORIGINAL ARTICLE

A readiness assessment framework for the adoption of 5G based smart-living services

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Abstract

The subject of this article is to analyze the users' attitude towards new, 5G-enabled smart living services before their commercial launch. The goal is to offer a framework for the analysis and evaluation of influential factors in the early adoption of 5G residential services. Additionally, the paper examines how mobile operators can leverage their existing infrastructure and services to boost the acceptance of both 5G as a technology and the provided smart-living services. To ascertain the potential impact that mobile operators can have on the adoption of such services, loyalty programs were taken into account as a separate factor in the acceptance study. The study was conducted in Serbia in the form of a survey. The analysis of the results yielded some notable conclusions such as trust in technology playing the leading role in influencing the behavior intention, while loyalty programs showed that they can influence attitudes towards individual smart living services. The presented results can be used to shape any future implementation of 5G-based services in Serbia, or any other country whose 5G infrastructure and services for the residential customer segment are yet to be established.

Keywords 5G · Smart residential community · Technology acceptance · Loyalty program

1 Introduction

The fifth generation of mobile networks (5G) is becoming reality all around the globe. While the initial focus of mobile operators was on the technology, their attention is now moving to the innovative 5G-based services.

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From the very first ideas about 5G, smart cities have been identified as one of the significant areas of application (ITU-R 2020). A wireless network capable of meeting diverse requirements and a vast level of heterogeneity, traffic volume, and connection density is anticipated to be one of the key enablers of the new smart environments (Alliance 2020). Reliable and resilient communication infrastructure is a prerequisite for the good performance of these new services in smart cities (Abreu et al. 2016). However, advanced technology and its superior performance are not sufficient to secure the success and sustainability of smart cities and communities (Winkowska et al. 2019). Recent works highlight the importance of meeting the actual needs and expectations of people when designing new intelligent environments (Burzagli et al. 2021). Their success requires a human-centric approach where technology serves as a sophisticated tool to address residents' needs and stimulates collaborative participation (Trencher May 2019). Mobile operators in particular are in a position where they can fulfill these needs, by diverging from their traditional role of infrastructure and communication services providers and becoming smart-living services providers.

The majority of the existing papers related to the role of 5G in the development of a new generation of smart cities, explore its innovation potential in the context of different public services or business improvements. This study addresses another domain: it focuses on the 5G-based services that the operators could offer to smart residential communities. Inhabitants of these communities and their needs represent the backbone of any smart residential ecosystem, and residents' acceptance of new services is crucial to their proliferation. The requests that these communities set before these 5G services must become a fundamental part of the offer. But before these requests can be even considered, the opinions and adoption readiness of these communities must first be understood.

In this paper, we assess the users' attitude towards 5G smart living services offered by mobile operators and examine their readiness to accept such services. Further, we analyze the key factors that are expected to determine the residents' acceptance. As mobile operators differ from usual smart service operators, they can naturally offer more diverse services and rely on integration with their existing infrastructure. For this reason, we explore the impact that loyalty programs can have on the acceptance of these services. In a further development, this can be used to address certain aspects of the privacy and security concerns of smart communities.

An evaluation of the acceptance of 5G smart-living services and loyalty programs was conducted through a survey in the Republic of Serbia. The results of the survey and the accompanying analysis are highly applicable for similar markets where 5G networks are still to be deployed, and those where the potential of 5G services for the residential customers have not yet been fully realized. For this reason, the results of the study can be utilized by mobile operators to embrace the role of smart-living services providers and to capitalize on their investment in 5G network technology in this yet untapped opportunity.

This paper is organized as follows. Section two provides an overview of the latest scientific and industry papers related to the main topics considered in this study. Section three outlines the development of the conceptual model and the hypotheses proposed in this work and further validated through the survey. Section four explains the survey, presents the findings, and analyses the results obtained. Section five presents the conclusions, limitations, and suggestions for future work.

2 Theoretical background

2.1 5G-enabled smart living ecosystems

The needs, habits, and preferences of the population living in urban areas have evolved over the last years, under the impact of different socio-economic and technological changes. The big study that Ericsson Consumer & Industry Lab conducted between October 2020 and January 2021 among participants in 31 countries, explored how the consumers' experiences and habits in daily life have been changed in the context of the COVID-19 pandemic, and how they foresee a new future urban reality for 2025 (Ericsson Consumer and IndustryLab 2021). It has confirmed that the pandemic has triggered a significant shift in people's behavior, accelerated digitization, but also resulted in raised expectations from the information and communication technologies (ICT) in the coming period (Ericsson Consumer and IndustryLab 2021). People expect to handle more of their needs, and especially their routine activities through connectivity and online services in the future (Ericsson Consumer and IndustryLab 2021). While they are looking for convenience through the different digital services, they are at the same time increasingly concerned about online privacy and security (Ericsson Consumer and IndustryLab 2021).

Topics that been explored by scholars as the potential area of IoT application as telerehabilitation (Vukićević et al. 2016), an intelligent home media center (Đurić et al. 2016), or the smart system to monitoring real-time microclimatic parameters (Dankovic and Djordjevic 2020), to name just few of them, became the real necessity of the modern citizen.

From the perspective of an individual resident or household in the urban area, the main needs can be grouped into categories (Ericsson Consumer and IndustryLab 20211; Thoughtlab 2021; Rinderud 2021): Digital infrastructure for remote work and education, access to information and entertainment, social contacts, health and wellbeing, mobility and transportation, homelife—including home security, home tasks, purchasing, and consumption (Ericsson Consumer and IndustryLab 2021; Thoughtlab 2021; Rinderud 2021).

To meet the technological and infrastructural requirements of these needs, new technologies are emerging. One such emerging technology is the fifth generation of mobile networks (5G), with its accompanying technological advancements, such as new radio technologies, telco cloud, Software-Defined Networking, Network Functions Virtualization, edge computing, autonomic management, and control, etc. (Alliance 2020). The 5G was designed to support different communication requirements from massive, machine-type communication to ultra-reliable, ultra-low-latency communication. These superior performances and end-to-end flexibility can be tied with other emerging technologies such as the Internet of Things and Artificial Intelligence, to make an excellent platform for the development and deployment of the next generation of smart living services (Alliance 2020; Rao and Prasad 2018; Agiwal et al. 2019).

Leveraging the capabilities of 5G networks, mobile operators can make different offerings to residential communities. The most straightforward one is a competitive and powerful wireless alternative to fixed broadband. Besides this, the operator can decide to move up in the value chain and offer innovative, smart services based on their mobile infrastructure to meet the growing technological needs of citizens. This change of business models implies that operators need to participate in different business ecosystems and even create new ones specific to their new services (Forum 2018; Bogdanović et al. 2021).

2.2 Residents' acceptance of the smart solutions and new technologies—related work

Despite the great technological advances in the IoT domain, the end-users are still resistant to using home IoT and smart-home solutions. In recent works, different aspects of users' privacy concerns have been identified as the important factors that prevent wider acceptance (Pal et al. 2021).

When it comes to 5G, in parallel with the increasingly big expectations, there is also a negative campaign oriented against it, spread mostly over the different social networks. A big study led by IPSOS in 21 European countries in 2020 (IPSOS 2020) has addressed people's awareness, the attitude towards 5G, and the opinion about widely spread 5G myths. The results showed that the positive/negative ratio in the general attitude towards 5G varies a lot between countries in Europe. A positive attitude correlates strongly with having a good understanding of 5G capabilities and it is more frequent among the younger population (IPSOS 2020). Significant for this study is the result about respondents' perception of the 5G importance for the different areas of use. While most of them consider that 5G will be important for the companies/business (85%) and the development of innovations (87%), they are less convinced about it becoming important for their day-to-day lives (67%) (IPSOS 2020).

To overcome these difficulties of opposing views and to better understand how they influence the acceptance of new technologies, acceptance studies must be undertaken. A most common framework for analyzing the acceptance of technologies is the Unified Theory of Acceptance and Use of Technology (UTAUT) which emphasizes the importance of four critical aspects that impact the adoption: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions (Venkatesh et al. 2003). Later, Venkatesh enriched the model (Venkatesh et al. 2012) by introducing three additional determinants—Hedonic Motivation, Price Value, and Habit–to be considered for the end-user behavior. This extended theory, UTAUT2 (the Extended Unified Theory of Acceptance and Use of Technology) (Venkatesh et al. 2012), is nowadays widely used as a basis for the assessment of an individual's intention to use new technology and in identifying the key influencing factors of acceptance and adoption (Tamilmani et al. 2021).

The wide application of the UTAUT2 model has resulted in numerous proposals for its extension for particular contexts, including the smart cities (Tamilmani et al. 2021). For example, for the acceptance of public safety solutions in the smart city Oliveira et al. (Oliveira and Santos 2019) suggested the introduction of a way to evaluate how the contribution of the city and the citizens can impact the adoption. For the acceptance of smart government services, authors in Almuraqab and Jasimuddin (2017) suggested the new variables: Perceived trust in government, Perceived trust in technology, Perceived Compatibility, and Awareness to be considered with the positive impact, while Perceived Cost and Perceived Risk are expected to harm the end user's attitude.

Yeh (2017) considers that the innovation concept has a positive impact on citizens' acceptance and usage of the ICT-based smart city services, while citizens' innovativeness has a positive moderative effect. In the extensive bibliometric analysis, Malchenko (2020), has identified a different set of factors, that according to the existing literature can influence people's intention to adopt smart city solutions. These factors include (Malchenko 2020): Motivation, Cognition, Digital skills and competence; Privacy concerns; Commitment, Attitude to the city, Participation in the city's life; Attitude, Subjective norm, Perceived behavioral control; Previous experience; Perceived ease of use, quality, and benefit; Enjoyment and attractivenessrelated to the new solution; Innovativeness and risk attitude; Civic trust; Age, gender, employment status and level of education.

For the subject of this paper, we have found that the model that suits the specifics of the subject matter the most is the Smart Cities Stakeholders Adoption Model (SSA) (Habib et al. 2020). SSA model is based on UTAUT2 and it specifies seven important factors that should be considered when planning smart-city services based on advanced information and communication technologies (Habib et al. 2020). Those factors are Self-Efficacy, Effort Expectancy, Perceived Security, Perceived Privacy, Trust in Government, Trust in Technology, and Price Value (Habib et al. 2020). While all of them are verified to influence to some degree residents' adoption of smart-city services, the following were found particularly significant: Trust in Technology (closely related to the perceptions of privacy and security); Trust in Government; and Price Value (Habib et al. 2020). There are many different influences on the decision to accept 5G. That is why, depending on the angle of observation and the aims of the researcher, several methods are often used in conjunction, to best capture the users' motivations.

2.3 The role of the loyalty programs in users' acceptance of new technologies

To enhance the acceptance rates of products or technologies, companies often turn to loyalty programs as one of the proven solutions. Smart cities, in particular, are starting to realize the benefits of loyalty programs, and are seeking to integrate them fully into their ecosystems. Loyalty program in the context of new, smart ecosystems is not mandatory an incentive for the acceptance of product or technology, it can be also a motivation for the change in users' behavior. There are some interesting works related to the loyalty systems applications such as in Poslad et al. (2015) where authors propose a platform that offers different incentives, such as rewards or recognition, to citizens who accept to adjust their mobility schemes in the city concerning the defined transportation objectives, with the end-goal of sustainable transportation within the city. Other approaches propose systems where the municipalities motivate citizens to participate in crowdsensing projects by paying them a certain amount, depending on the spent time or the amount of collected data (Lindsay 2018).

There are also practical implementations, proof of concept or pilot projects where different reward and loyalty programs are used to stimulate and accelerate the change of citizens' behavior, but also to educate them about reasons for such a change. The areas of applications are different, from sharing e-bikes (E-bike provider launches reward programme for sustainable travel—Smart Cities World 2022), and changing transport preferences (Seattle transit operator introduces mobility rewards and incentive programme—Smart Cities World 2022), to spending more time in local parks and green spaces (Belfast rewards its citizens for spending time in green spaces—Smart Cities World 2022), and stimulating local purchasing (Boston rewards citizens for shopping locally to aid recovery—Smart Cities World 2022). Although these practical examples are not directly related to the adoption of the new technology, they provide some meaningful insights into the users' preferences. In all of them, a mobile application is used for the user interaction, in some cases even gamification elements are added to achieve better user engagement (E-bike provider launches reward programme for sustainable travel—Smart Cities World 2022). Another interesting point is that besides the direct benefits to the end-user (e.g. cash or cash equivalents like free minutes, tickets, etc.) some new loyalty programs offer their participants the possibility of donating their rewards to the community (Belfast rewards its citizens for spending time in green spaces—Smart Cities World 2022).

While loyalty programs can rely on different business practices and technologies, blockchain-based loyalty programs are becoming increasingly popular. This popularity is mostly due to the technology's built-in transparency, which facilitates trust both between the loyalty service provider and between users themselves who can freely trade their loyalty points. Another reason is related to the use of smart contracts to enable complex use-cases and facilitate both manual and automated trade of loyalty points (Agrawal et al. Aug. 2018; Bulbul and İnce 2018). By relying on transparency and smart contracts, privacy and trust concerns of individual users can be addressed, which are the aspects that are becoming increasingly relevant to the new userbase. Among the numerous blockchain use cases in the domain of smart cities and smart environments, scholars identified different loyalty programs in the fields such as tourism, shared vehicle services, payments, etc. (Pilkington 2017; Nam et al. 2019), or in a broader context, a loyalty platform which enables collaborative loyalty program that connects companies, smart city organizations, government, and consumers into a single network (Bogdanović et al. 1367).

3 Methodology

3.1 Research context and the main questions

In this paper, we examine the factors that impact the adoption of the 5G-based services among the users in the residential community. The scenario considered in our analysis assumes a mobile operator in the role of the key stakeholder of the smart ecosystem that offers both 5G services, alongside smart-living services. Additionally, it is assumed that the 5G operator can initiate a loyalty program to increase the acceptance rate of such services.

The main research questions evaluated in our study are the following:

1. What is the interest in smart services in the daily life of residential communities?
2. What are the factors that can impact the acceptance of smart living services based on 5G?
3. What is the role of the loyalty programs in users 'acceptance of new services?

3.2 Conceptual framework and hypothesis

Common for all the research questions above is that they are addressing behavioral aspects. Due to a lack of concrete implementations of 5G in Serbia, and the lack of local studies of user's behavior in 5G, it is not an easy task to answer on them. To overcome this challenge, we have proposed a new conceptual framework. It is based on the literature reviews in the chapter 2, primarily on the extended Unified Theory of Acceptance and Use of Technology (UTAUT2 model) (Venkatesh et al. 2012) and the Smart Cities Stakeholders Adoption Model (SSA model) (Habib et al. 2020), but with the adaptations for this particular context and environment.

UTAUT2 (Venkatesh et al. 2012) and most of its derivates evaluate Behavioral intention to assess users' readiness for new services. In our study, due to the already explained reasons, readiness for the acceptance of the 5G-based smart services is examined from two perspectives: Interest in individual services and Intention of using 5G-based smart living services once they become available. Consequently, we propose two dependent variables in our model.

In the process of selection of independent variables, we made evaluation of those already proposed in the UTAUT2 model (Venkatesh et al. 2012) and the Smart Cities Stakeholders Adoption Model (SSA model) (Habib et al. 2020), their applicability in the given context and their capabilities to produce a positive impact on users' attitude toward 5G smart living services.

Both above mentioned models and many others, contain construct called Effort expectancy. In different contemporary studies it has been proven as s a crucial predictor of technology acceptance (Chao 1652), thus we have evaluated it as applicable for our case.

Although not present in the original UTAUT2, Trust has been identified by researchers as important factor to influence Behavioral intention (Almuraqab and Jasimuddin 2017; Malchenko 2020; Chao 1652; Alalwan et al. 2017). SSA model (Habib et al. 2020) differentiate Trust in technology and Trust in government as two key factors influencing users' behavior. Considering results of IPSOS (2020) we find the construct Trust in technology applicable for partial reuse, defining it in our context as the "general attitude that user have towards 5G technology". Trust in government in our case is replaced by Trust in operator, as mobile operator is supposed to be the key player in the environment. Additionally, one of the main assumptions for the depicted scenario is that operator can leverage on the existing relationship with the residential subscriber base and it should be one of its main advantages in comparison with other players capable to offer smart living services.

Increasing importance of the security and privacy for the acceptance of the smart (Ericsson Consumer and IndustryLab 2021; Pal et al. 2021; Malchenko 2020; Habib et al. 2020) has been reflected in the construct Perceived security and privacy.

Performance expectancy, Facilitating conditions and Habit constructs from UTAUT2 model (Venkatesh et al. 2012) were excluded due to the fact that in our case users do not have any practical experience with the services in question. Hedonistic motives could be applicable for one subset of smart living services (e.g., entertainment), but not on a full scope we are targeting.

For two constructs from the original UTAUT2 we have proposed replacement. Instead of Social influence we propose Co-creation expectancy following the conclusion from the recent academic works about the importance of the co-creation and cooperation with the citizens in the new generation of smart communities (Giourka 2019; Gohari 2020; Cardullo and Kitchin 2019).

Instead of Price value which is not applicable due to the lack of commercial services, we introduce Benefit expectancy, as anticipated value for the end-user. Additionally, we assume that this can be a moderating variable, i.e. that it can moderate the impact created by Trust in technology and Perceived security and privacy.

Finally, we propose Loyalty program as a new variable. Despite the extensive literature related to loyalty programs, the success of such an incentive mechanism in the context of 5G-enabled smart living services has yet to be studied. Although the introduction of this variable was inspired by papers dedicated to blockchain-based loyalty programs reviewed in chapter 2.3 above, we put the focus on user interest in such a program and the moderating effect that incentives can produce rather than on a technology in which the loyalty platform will be implemented.

An overview of the variables used in our model is given in the table below (Tables 1, 2).

The following hypotheses are set:

H.1–H7 The independent variables listed above are correlated with the residents' intention (BI) to use new smart living services based on 5G.

H.8 The effect of Trust in operator towards residents' intention to use smart living services is moderated by the Loyalty program.

H.9 The effects of Trust in technology and Perceived privacy and security towards residents' intention to use smart living services are moderated by the Benefit expectancy.

H.10 The impact of each independent variable is moderated by the demographic data (age group, education, and employment status), but not by the gender of the respondents.

Table 1 Proposed Variables

Dependent Variable	Description	References
Interest in individual services Behavioral intention	Introduced to substitute for concrete behavioral input	Based on the Behavioral intention variable of UTAUT2 (Venkatesh et al. 2012) and SSA (Habib et al. 2020)
Independent Variable	**Description**	**References**
Trust in technology	The end-users general perception of 5G	Based on eponymous variable from SSA (Venkatesh et al. 2012), but in our model, it is considered as independent of Perceived security and privacy
Effort expectancy	Anticipated easiness of use	UTAUT2 and SSA models (Venkatesh et al. 2012; Habib et al. 2020)
Co-creation expectancy	Expected involvement of the end-users in the development and the life cycle management of the new services	A new variable, proposed as a replacement of the Social influence from the original UTAUT2 (Venkatesh et al. 2012),
Perceived security and privacy	End-users view on those aspects in the context of new smart living services	Combination of the constructs Perceived security and Perceived privacy from the SSA model (Habib et al. 2020)
Trust in operator	End-users perception of the operator's capabilities of playing the key role in the smart ecosystem	A new variable was created using the analogy with the Trust in the government from the SSA model (Habib et al. 2020)
Benefit expectancy	Anticipated value. Since there is no commercial 5G yet, we are focusing on the expected benefits	New variable proposed as the replacement of the Price value from the UTAUT2 and SSA (Venkatesh et al. 2012; Habib et al. 2020)
Loyalty program	End-users interest in the loyalty program related to the usage of smart-living services	A new variable was introduced in the model

Table 2 Demographic data

Variable	Values	Frequency	Percentage (%)
Age group	Born before 1960 (Baby boomers)	4	2.06
	Born in the period 1961–1980 (Gen X)	40	20.62
	Born in the per. 1981–1995 (Gen Y)	39	20.10
	Born after 1995 (Gen Z)	111	57.22
Education Level	Primary	4	2.06
	Secondary	81	41.75
	Bachelor's or equivalent	73	37.63
	Master's or doctoral	36	18.56
Occupation	Secondary school student	3	1.55
	University student	101	52.06
	Employed	73	37.63
	Unemployed	11	5.67
	Retired	5	2.58
Gender	Female	86	44.33
	Male	108	55.67

The research model can be seen in Fig. 1, in the results section.

3.3 Survey participants

This survey was performed during the summer of 2021 among the population in Serbia and it examines the opinions of 194 participants. The survey participants were presented with the idea of a 5G service operator, smart-living services, and the loyalty program. Main demographic data about the participants are summarized below:

Table 3 summarizes the participants' responses, based on their knowledge of 5G and the main sources of information.

3.4 Instruments

The questionnaire created for this research was anonymous and consisted of two parts. The first one was focused on demographic information, while the second part contained 43 questions, derived from the main research questions listed above. Two of them addressed respondent's knowledge of 5G, while the remaining 41 questions were answered using the 5-point Likert scale, grouped as follows:

- Trust in technology (TT1–TT4)
- Interest in individual services (IS1–IS8)
- Effort expectancy (EE1–EE3)
- Co-creation expectancy (CE1–CE3)
- Perceived security and privacy (PS1–PS2)

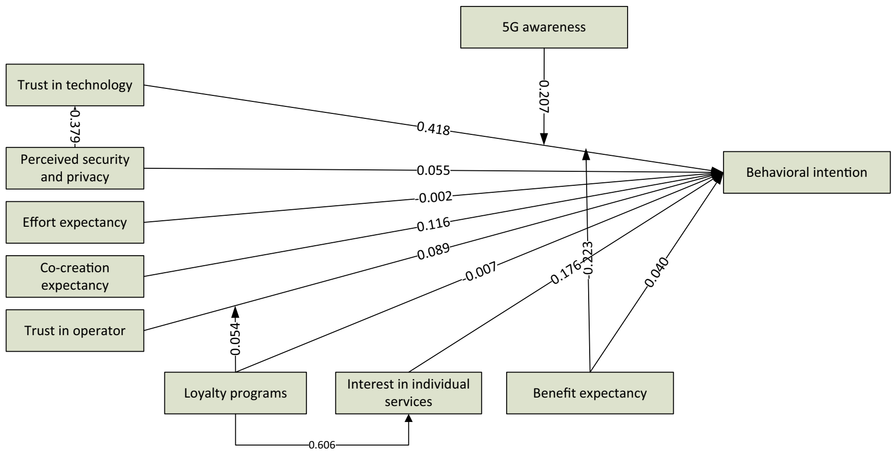

Fig. 1 Results of application of PLS algorithm

- Trust in operator (TO1–TO4)
- Benefit expectancy (BE1–BE5)
- Loyalty program (LP1–LP9)
- Behavioral intention (BI1–BI3)

To minimize biases, the majority of questions are formulated neutrally: e.g., "to what extent do you expect/agree/etc." and there are both positive and negative statements. Consequently, answering with 1 is not in all the cases a negative, nor answering with 5 is always a positive opinion, but the answers were coded and normalized before the analysis.

To overcome the fact that both 5G and smart living services could be an esoteric topic for some respondents due to the lack of proper information, all the sections are preceded by a short description.

4 Results and analysis

4.1 Interest in 5G services in smart residential communities

Table 4 presents average values, standard deviations, and confidence intervals for the survey questions. Generally, the results were relatively positive regarding all of the constructs, although lower scores were given on questions related to the concerns about health effects.

Table 5 presents respondents' interest in individual services. The overall interest that respondents showed was good, with the total average rate > 3.63. Service that has received the lowest rate is the one related to the optimized food purchasing (IS1) which can be caused by users' perception that it is not needed/not useful or by the concern related to privacy. The highest rates are associated with surveillance

Table 3 Knowledge and sources of information about 5G

Variable	Values	Frequency	Percentage (%)
5G Awareness (Have you already heard about 5G?)	Yes, I know very well what it is	86	44.33
	Yes, I have a rough idea of what it is	87	44.85
	Yes, but only by name	19	9.79
	No, I haven't heard anything about it	2	1.03
The main source of your information about 5G? (multiple answers allowed)	Lectures at your school/university	44	
	Friends, family, colleagues	52	
	Magazines or websites specialized in ICT	115	
	Social networks	79	
	Traditional media	96	

Table 4 Survey results

		Mean	SD	95%CI
Trust in technology				
TT1	To what extent do you expect 5G to improve business and other areas of our lives?	4.08	1.01	0.14
TT2	To what extent are you concerned about the harmful effects that 5G might have on our health or the environment?	3.30	1.38	0.19
TT3	To what extent are you convinced that before the launch of the 5G network, it will be ensured that there are no negative effects on our health or the environment?	3.02	1.32	0.19
TT4	What is your overall opinion on the 5G network capabilities?	3.93	1.10	0.15
Effort expectancy				
To what extent do you expect new, 5G-based smart living services, to fulfill the following				
EE1	Easy to use for an average user	4.12	1.00	0.14
EE2	Easy to learn	4.26	1.07	0.15
EE3	Easy to train others how to use them	4.14	1.00	0.14
Co-creation expectancy				
CC1	You and your neighbors will be able to influence the development of such services to get what is needed for your residential community	3.72	1.31	0.18
CC2	There will be services tailor-made to the needs of different groups (e.g., teenagers, students, employees, retirees)	4.05	1.14	0.16
CC3	Inhabitants who wish to do so can be involved in testing new services for the whole residential community	3.73	1.26	0.18
Perceived security and privacy				
PS1	Such services will include all the mechanisms to protect against unauthorized access to your personal data or property	4.35	1.07	0.15
PS2	It will be safe for you and your family to use such services	4.51	0.96	0.14
Trust in operator				
A mobile operator would play a significant role in the implementation of such services. To what extent do your expectations match the following statements				
TO1	Your mobile operator will be able to offer smart services that will be safe to use	4.26	1.08	0.15

Table 4 (continued)

		Mean	SD	95%CI
TO2	You will be able to get complete information from your mobile operator about all the data related to you or your family, collected using smart services	4.04	1.29	0.18
TO3	Your mobile operator will have the capabilities and procedures to protect the privacy of your data	4.21	1.22	0.17
TO4	The mobile operator will share with a third party your personal data only if it has previously obtained your consent	3.68	1.49	0.21
Behavioral intention				
To what extent do the following statements match your plans and intentions, once such smart services become available				
BI1	I intend to use them	3.77	1.22	0.17
BI2	I intend to use them only if necessary	3.98	1.19	0.17
BI3	I will recommend to my family members and neighbors to use them	3.71	1.29	0.18

Table 5 Interest in individual services

	Short description of the presented 5G-enabled service	Mean	SD	95%CI
IS1	Sensors in your household monitor the food stocks, as well as your habits regarding their consumption, to optimize the purchasing (delivery time and quantity)	2.89	1.50	0.21
IS2	Improved monitoring of your apartment, building, residential area and more effective protection against burglary, fire, flood	4.11	1.26	0.18
IS3	Real-time monitoring of the important health parameters of your family members who need it (e.g., elderly, patients recovering from surgery, or those with chronic disease …) and the possibility to get medical advice or get in contact with the doctor	4.02	1.29	0.18
IS4	Autonomous vehicles to be used for delivery	3.27	1.53	0.21
IS5	Drones to be used in case of urgent or important deliveries (e.g., medicine or spare part)	3.82	1.45	0.20
IS6	Immersive entertainment over a mobile network (AR / VR games, virtual visits to museums, concerts, sporting events, etc.)	3.41	1.39	0.20
IS7	Sensors to monitor the amount of waste to optimize garbage collection	4.07	1.31	0.18
IS8	To have a digital handyman (with the help of smart glasses and gloves), and the assistance of a real or virtual expert, so you can fix things yourself	3.50	1.48	0.21

Table 6 Benefit expectancy

	To what extent do the following statements match your expectations in terms of benefits from such services	Mean	SD	95%CI
BE1	I expect direct benefits for my family and myself (saving money, improved quality of life)	3.77	1.29	0.18
BE2	I expect benefits for my community	3.61	1.33	0.19
BE3	I expect benefits for society (reduced pollution, optimal use of resources, reduced waste …)	3.88	1.29	0.18
BE4	I expect benefits to justify their price and the price of the 5G devices	3.88	1.24	0.18
BE5	I do not expect any benefit	3.38	1.47	0.21

services (IS2), intelligent waste management (IS7), and e-health (IS3). A potential reason for this result can be the fact that those services and their value are easy to understand.

Table 6 shows the results regarding the benefit expectancy. The score is not high, but they tend towards higher scores.

4.2 Factors that impact the acceptance of 5G services in smart residential communities

The examination of cause-and-effect relationships was performed using the PLS-SEM method, which provides explanations of the variances of the variables without requiring specific data distributions. We have performed the evaluations of both connections between experimentally collected data and variables observed in the model, as well as relationships between variables in the model. More detail about the PLS-SEM method is available in the literature (Hair et al. 2011, 2013, 2014; Sarstedt et al. 2014; Gudergan et al. 2008; Reimann et al. 2009). The analysis was conducted using SmartPLS 3.0 software tool (Ringle et al. 2015).

The results of the application of the PLS algorithm are shown in Fig. 1. The figure shows only the constructs and relationships relevant for further analysis, although we considered a wider set of relationships, as indicated in the methodology section. Higher positive values indicate stronger correlations, while values close to zero indicate no correlations. The results suggest that the strongest effect on Behavioral intention comes from the Trust in technology. Additionally, it shows the importance of the variable 5G awareness, which we initially considered only in profiling respondents.

Table 7 presents an assessment of the reliability and validity of the measurement model. Average Variance Extracted (AVE) parameters, which consider the existence of a positive correlation between indicators describing a single variable, are all above the recommended value of 0.5 (Hair et al. 2014), leading to the conclusion that the survey was well-designed. In addition, the values of Cronbach alpha and the composite reliability parameter are in the recommended interval between 0.70

Table 7 Validity assessment of the measurement model

	Cronbach's alpha	Composite reliability	Average Variance Extracted (AVE)
Behavioral intention	0.903	0.939	0.837
Benefit expectancy	0.896	0.928	0.763
Co-creation expectancy	0.794	0.879	0.708
Effort expectancy	0.821	0.892	0.733
Loyalty program	0.893	0.917	0.649
Perceived security and privacy	0.879	0.941	0.889
Trust in operator	0.855	0.912	0.777
Trust in technology	0.807	0.874	0.635

and 0.95, indicating that the internal consistency of the survey was acceptable (Hair et al. 2011, 2014; Sarstedt et al. 2014).

The Fornell-Larcker validity criterion, used for discriminant validity assessment (Fornell and Larcker 1981) was met for all variables.

The next step in the analysis included the assessment of the structural model. Collinearity was evaluated using the variance inflation factor (VIF). All values obtained are below 5, indicating that there is no collinearity of the variables (Table 8) (Hair et al. 2014).

The coefficient of determination (R^2) was used to estimate the predictive accuracy of the model. The obtained value is 0.683, which is considered relatively high in user behavior research. Further estimation of the predictive relevance of the model was realized using the blindfolding technique and calculating the Q^2 value, which is 0.537. Since models with a Q^2 value of 0.35, or higher, are considered to have high predictive accuracy, it can be concluded that the model in question has good accuracy.

The relationships between the considered variables were analyzed using path coefficients of the structural model. The results reveal that trust in technology has the strongest positive impact on behavioral intention, while co-creation

Table 8 VIF values

	Behavioral intention
Benefit expectancy	3.493
Co-creation expectancy	2.878
Effort expectancy	1.921
Loyalty program	2.713
Perceived security and privacy	3.847
Trust in operator	2.568
Trust in technology	2.485
Interest in individual services	2.663
5G awareness	1.482

expectancy and benefit expectancy also show positive relationships. No strong negative relationships were detected.

More detailed significance analysis was done using the bootstrapping method with 5000 samples and with a significance of 5%. The results where statistical significance was obtained are shown in Table 9.

The results show that the influence of Trust in technology is statistically significant for Behavioral intention, as well as 5G awareness. Although Loyalty programs and Perceived security and privacy do not have statistically significant influence, they are closely related to the Trust in technology and Interest in individual services, respectively, and therefore can influence the Behavioral intention as mediators. The influence of Loyalty programs on the Interest in individual services is further investigated in the next section.

4.3 The role of the loyalty programs in users' acceptance of new services

In addition to the benefits of the services themselves, the operator can offer incentives (loyalty points) for the use of these services or participation in their development and testing. Although the previous analysis shows that loyalty programs do not impact the behavior intention, they can be used as a powerful tool for stimulating users in smart residential communities. Results presented in Table 10 show that users are mainly interested in hard, tangible benefits (LP4, LP5) vs. soft benefits (L8) which can be explained by demographics of respondents (only 37.63% of them are employed). Consequently, the most of respondents opted for the possibility of spending their loyalty points for bills reduction (LP4). Possibility to offer benefits related to the other legacy or new, smart services from their portfolio is the significant advantage that mobile operators have in comparison with the other players that might offer smart residential services. The other result that could be of interest to the operator considering a loyalty program, is that the participants in such a program do not have to be the ultimate recipients of benefits. High results related to the possibility of donating to charity (LP5), or contributing to the benefits for community (LP9) are in line with the characteristic of post-Millennials to care about the

Table 9 Testing the hypotheses

	Original sample	Mean	Std. dev	T statistics	*P* values
Trust in technology—> Behavioral intention	0.418	0.416	0.077	5.445	0.000
5G awareness—> Behavioral intention	0.207	0.206	0.056	3.712	0.000
Loyalty program—> Interest in individual services	0.606	0.61	0.052	11.717	0.000
Interest in individual services—> Behavioral intention	0.176	0.173	0.082	2.151	0.033
Perceived security and privacy—> Trust in technology	0.379	0.381	0.076	4.96	0.000
Benefit expectancy moderates Trust in technology—> Behavioral intention	–0.223	–0.189	0.07	3.188	0.002

Table 10 Loyalty program

	To what extent do the following statements match your expectations or interest	Mean	SD	95%CI
LP1	Operator to offer incentives (loyalty points) to those who use smart services or participate in their development and testing	3.60	1.30	0.18
LP2	Information on collected and spent points to be reliable and easily accessible	3.91	1.18	0.17
LP3	There will be flexibility in using these points (e.g., the possibility of transferring them to another user or community, the possibility of using them instead of money for other smart services, etc.)	3.80	1.28	0.18
	Scenarios of using loyalty points for which the respondents rated their interest			
LP4	Reduction of bills for mobile operator's services (both traditional and new ones)	4.21	1.13	0.16
LP5	Donation to charity	3.96	1.29	0.18
LP6	Purchase of 3rd party products or services	3.59	1.33	0.19
LP7	Privileges in using other services within the city or community (e.g., parking place, tickets for cinema or theater)	3.81	1.31	0.19
LP8	Having a bigger influence in the decision-making process concerning your residential community (e.g., right to weighted vote)	3.14	1.48	0.21
LP9	The right to win a smart service for your community together with other residents (e.g. smart watering of common green spaces)	3.83	1.35	0.19

others, society and environment, which is already identified in the literature (Jose et al. 2022). Finally, high rates associated to the importance of reliability of information related to loyalty points (LP2) and flexibility in their further usage (LP3) are important input for the design and implementation of the loyalty platform. As mentioned in 2.3, these requirements can be met by using built-in features of blockchain technology, although this is not the only option available. The main reasons in favor of the blockchain-based approach are the ongoing attempts of the telco operators worldwide to apply this technology in their business processes (TR279 CSP Use Cases Utilizing Blockchain v3.1.1—TM Forum I TM Forum 2021), the potential of future usage of such a loyalty platform in the broader context of the smart city (Bogdanović et al. 1367) and a prospect of using blockchain for the different public services (Cagigas et al. 2021). Main raison against this approach is high cost related to the deployment of blockchain infrastructure However, the high costs of blockchain solutions are expected to be reduced in the future, as the new, more efficient, consensus algorithms are being developed (Yang et al. 2019).

Further analysis of correlations of the influence of the loyalty programs on individual services is presented in Fig. 2. All the correlations are statistically significant, with $p < 0.001$. The higher values of path coefficients indicate which smart living services are expected to benefit most from the inclusion in the loyalty program.

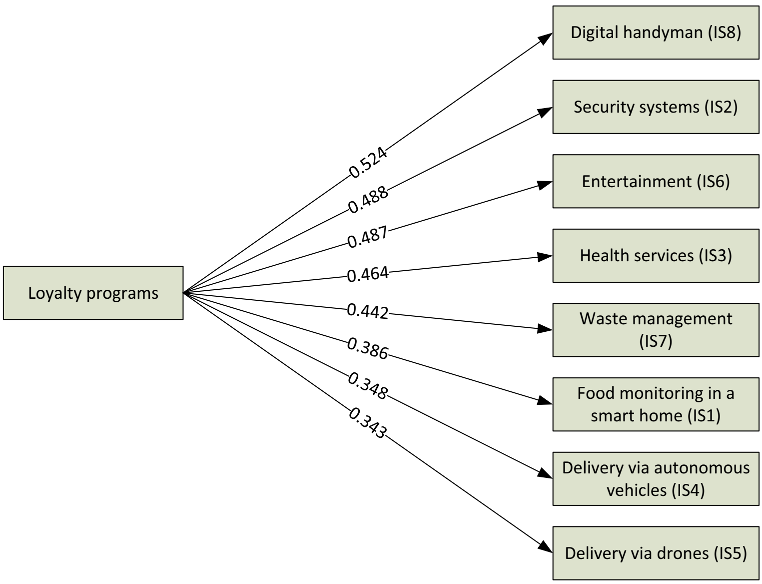

Fig. 2 Path coefficients for correlations of loyalty programs and individual smart living services

5 Discussion and conclusions

The survey conducted in this study found high expectations among respondents about 5G and its innovation capacity. There was considerable general interest in individual smart living services. Therefore, this is important information and business opportunity for the operator to plan and develop a new offering for the residential segment.

Concerning factors that affect user adoption, we identified Trust in technology as a crucial factor for behavioral intention. This correlates with the conclusions of other academic works (Habib et al. 2020). Although it has an indirect impact, Perceived privacy and security, usually closely related to the Trust in technology (Habib et al. 2020; Braun et al. May 2018), was not seen as an important isolated factor in the results of our study. Other factors that are significant to behavioral intention are Interest in individual services and 5G awareness. This confirms the thesis on the need for citizens' education and active involvement in this area (Giourka 2019; Gohari et al. 2020; Cardullo and Kitchin 2019). In addition, the expectation of benefits moderates the influence of Trust in technology on Behavioral intention.

The main implications and recommendations for any mobile operator looking to become a smart-living service provider are as follows:

- Educate the end-users. Considering the importance of the Trust in technology and the 5G awareness factors and explaining the real value and benefits of 5G, preferably without using high-tech terminology to reach a wider subscriber base. These activities should be completed beforehand, before the commercial implementation of 5G smart living services.
- Gradually build confidence and new services. The introduction of smart living services should gradually build awareness and trust with the end subscribers. To provide this type of new service, mobile operators often need to build a partner ecosystem. The recommendation in this area is to carefully select partners, considering the impact of this partnership on the subscriber's perception of trust, privacy, and security.
- Encourage early adopters and use the loyalty program as an incentive for the users. Respondents are mainly interested in using loyalty points to lower their bills for other mobile operator services. It is an opportunity for the operator to create a competitive advantage in the marketplace by using cross-bundling and cross-promotions, together with other services, to stimulate the usage of the new 5 G-based services.

There are two main theoretical contributions of this paper. The first is in the proposed modification of the UTAUT2 (Venkatesh et al. 2012) and the SSA model (Habib et al. 2020) for the evaluation of the factors which impact the adoption of new services in smart communities. It enriches the existing models by taking into consideration citizens' engagement (i.e.co-creation), which is the important success factor in the new generation of smart cities. Furthermore, the proposed model introduces the expected benefits and incentives instead of price value. This makes it suitable for the application before the commercial launch of the new services/new technologies. The results obtained may be very useful for mobile operators and other stakeholders looking to provide services in the early stages of 5G networks. Moreover, it can be used to shape their initial strategies and subsequent steps. Likewise, the modified UTAUT2 model provided by this study may be used by the operator to assess the right timing for the launch of smart residential services and appropriate incentive mechanisms.

The second contribution is related to the validation of the role that a loyalty program could have in the broader adoption of the new smart living services and users' expectation from such a program. The high rate associated with the importance of reliability and accessibility of the information about loyalty points (LP2) confirms that the blockchain could be a good choice of technology for the development of a loyalty platform. This proposal should be evaluated in the detailed cost -benefits analysis, however if the operator is aiming to have a broader role in the smart city ecosystem, introduction of the blockchain-based loyalty platform as proposed in Bogdanović et al. (1367), can be a justifiable investment. By leveraging the fact that the loyalty program works within a smart city, the 5G operator can offer the added concepts of social responsibility, crowdsourcing, and participation, alongside the benefits provided by their existing mobile network services. Additionally, as privacy is built into the platform, users can be swayed by companies to disclose their personal information in return for direct benefits.

The limitation of the study is demographic. The results represent the interests of the urban population, mainly young people in Serbia, in the new services based on 5G and their readiness to use them. Without a commercial 5G network in Serbia, their perception of technology and new services has not been shaped by experience, but rather by different sources of formal and informal information. Consequently, the lack of behavioral involvement is the major limitation of our research. However, the lack of behavioral factors in the model was offset by the addition of two new variables with the sole objective of replacing actual behavioral data.

Future work should address a broader and more diverse respondent base, preferably after the 5G network rollout. After the commercial launch of the 5G, the impact of the price value on behavioral intention can be evaluated and these results can be combined with the conclusions given in Femminella et al. (2018) when deciding on pricing strategy for future smart services. Comparing the results of this paper with future studies should likewise provide valuable information on how 5G rollouts and practical experience affect the acceptance of 5G technology.

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Declarations

Conflicts of interest Not applicable.

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