A Proposed Approach for Agile IoT Smart Cities Transformation– Intelligent, Fast and Flexible

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***Abstract*—Smart city architectures have been varying from one community to another. Each community leader develops their own perspective of smart cities. Some of these communities focus on data management, while others focus on provided services and infrastructure. In this research, an attempt to propose a clear, complete, and efficient perspective of smart cities is accomplished. The proposed generic architecture clarifies the full capabilities, requirements, and layers' contribution to a successful smart city development. The proposed architecture utilizes Internet of Things tools as well as agile standards in the description of each layer. The research aims to discuss each layer in detail, the relationships among layers, the applied technology, and every aspect that leads to the success of using the recommended architecture. Although smart cities, IoT, and agile research have previously tackled the relation of each one of them with the other, up to the researchers' knowledge, the three paradigms have not been previously considered as a unified collaborative approach. In order to reach the research target, the proposed architecture intelligently utilizes these paradigms and presents a robust architecture with high-quality standards.**

Keywords*—*Smart city; agility; Internet of Things; cloud computing; intelligent systems

I. Introduction

Smart cities can drive intelligence to every aspect of the lives of the population. It affects management, decision-making, culture, and regularities. Smart cities consider re-inventing the way of living while generating value for the public. The main objective for developing smart cities is to enhance the quality of the population's way of living and provide them with an easy, sustainable, and satisfying life either in social or professional directions. In order to reach this goal, it is vital to identify all the requirements, obstacles, and challenges to be able to build smart cities. The term "smart city" has been tackled in different research studies; however, other aspects related to information technology are usually associated with it. The continuous population growth has become a primary reason for services' quality and hinders the development. Almost all fields have been affected by this exponential population growth, such as education, health, energy, and many others. Smart city development has been an effective solution supporting the city's sustainability. Quality is an associated aspect of smart cities. Embarking digitalization is vital for smart cities' transformation. Utilizing recent technology, initiating new regulations, motivating the economy, and other factors are related to the concept of smart cities [1].

The idea of smart cities emerged in the nineties. The first wave focused on the contribution of the information technology concept to the main cities' infrastructure. Then, a focus on the community and its players highlighted how these players can have an easier life in smart cities. Later, smart cities term has been closely related to digitalization and intelligence; several factors effect has been discussed, such as people's resistance, the communities' culture, and others. Along the journey of smart cities' emergence, a broader perspective was highlighted, including the service's intelligence such as transportation systems, electricity system [2], construction field, banking systems, and others. These perspectives strongly emphasized the sustainability value of the cities' resources.

The concept of a smart city is exponentially increasing either for small or large cities. This global emergence drove the world to initiate new rules and regulations for the new era of cities. Many investments in smart cities have been proposed with the objective of innovation, growth, and enhancing life. All existing architectures depend mainly on the enabled technology for the smart features of the community. It has become feasible now to develop smart cities with the current acceptance and interoperability of IoT and advanced data analysis. Another perspective of smart cities is the ability to smart intelligent decisions by utilizing intelligent techniques for predictive analysis, better planning, and management [3]

This research traces all the proposed architectures for smart cities, traces the findings for embedding the technologies in the architectures infrastructures, and identifies the regularities and critical aspects for the transformation goal. This research proposes a generic architecture for smart cities, which is applicable for implementation with all its aspects, however, flexible. The proposed architecture discusses six layers and contributors to each one with giving the implementers the opportunity to implement the valid component without affecting the remaining architecture. Several factors are related to the concept of smart cities development including culture, quality, acceptance, resistance, and sustainability. These factors will be discussed later in this research. Moreover, other emerged factors such as IoT, agility, and motivating population are also considered as pillars in the proposed architecture.

II. Related Work

IoT devices strongly contribute to smart cities as one of the main pillars. The devices are considered as sources that provide numerous amounts of data. Therefore, unification to a single data model is recommended, which should be able to deal with such data. Several researchers have proposed different models to deal with the data heterogeneity, temporal, and complexity. The research [4] included a model that received data from IoT devices and determined the correlation between the growth of both industries and urban. The research concluded that managing knowledge directly influences the development of the industry. The study recommended that the enterprises' technological communication enhances knowledge management and promising technologies investments which leads to alliance flexibility. Qian et al. (2019) [5] discussed the positive impact of IoT technology on empowering the infrastructure and, consequently economic growth and sustainability. Chen et al. (2020) [6] focused on the contribution of IoT technology and deep learning techniques in construction field. The research concluded that these contributing fields have leveraged the process of construction by exploring the shortest time consumed in the evacuation process. Watson et al. (2020) [7] also focused on IoT's contribution to the construction of smart cities and concluded that the field still needs further research for further development requirements of IoT technologies to leverage the construction of smart cities.

Focusing on cloud computing contribution in smart cities. Lv et al. (2018) [8] proposed a platform for smart cities in which cloud computing and geographical information systems successfully contributed. The research highlighted that both fields could positively affect the success level of monitoring environment phenomena and predicting expected disasters as well as exploring transportation system performance. Hossain et al. (2018) [9] highlighted the need for cloud computing platforms for higher computing technology when contributing to IoT devices access in smart cities such as edge computing for more effective computations and latency avoidance. Javadzadeh et al. (2020) [10] focused on the same latency issue and proposed the same fog computation solution. Giannakoulias et al. (2019) [11] focused on the security issues of cloud environments and their effect on smart cities platforms as well as [12]. The research in [13] highlighted that IoT and cloud computing contribution in smart cities enhances the services performance with the ability to reduce the servers' load as well as reducing their number which greatly contribute the construction cost.

The previous research highlighted the positive contribution of both IoT and cloud computing with focusing on a determined subject, however, up to the researchers knowledge, there was no research that provided a complete perspective of smart cities which is one of the vital issues to present the whole smart cities pictures, the interaction between all contributing aspects and the need for homogenous cooperation among all contributing players. Moreover, the research [14] discussed the issues of smart cities and confirmed that there is no complete structure for smart cities while all current projects are pilot individual projects that included trade-offs of some aspects over the others.

III. Research Contribution

To be able to present a complete flexible generic platform, twelve platforms have been extensively studied. These platforms have been developed by international organizations following the required standards. Moreover, different projects and studies have been also studied. The aim of this extensive study is to explore the characteristics of a smart city architecture including core, extendable, and supportive characteristics. Ensuring the collecting of all aspects reflects that the proposed platform proposes the best practice when compared with any other platform. This comparison will be performed in the evaluation section. While there were differences between the collected platforms, however, it was also clear that common segments could be highlighted. Extensive study has been performed to explore the strength and weakness between these platforms which lead to the initiative for a generic platform that provide solutions to hinder the possible obstacles and fully consider the reality of cities. The proposed platform has taken into consideration the international standards, system requirements, services, data, and security management criteria for smart cities [16].

IV. A Proposed Agile IoT Architecture

Different smart cities platforms recommendations have been studied aiming to explore the possibility to propose a successful platform with maximum interoperability with the common infrastructure of cities [15]. This target ensures accepting the proposed platform and encourages its implementation. The authors also aimed at proposing a generic platform which utilizes the commonly used technologies to ensure its implementation adequacy in different environments. The proposed generic platform that could be implemented using different technologies with various levels of maturity. The proposed platform could also be easily extended or reduced according to the capabilities; the platform flexibility will be discussed in detail in the following sections.

The proposed architecture (Fig. 1) consists of five main layers in addition to a continuing monitoring and governance layer. Each layer components will be discussed in detail in the next subsections. Moreover, Fig. 1 illustrates the proposed architecture.

The following key aspects identify the smart city platform that fits with the available capabilities.

- Identify the needed capabilities and the specifications for each capability.
- Ensure the delivery of the required capabilities with sufficient flexibility.
- Ensure all compliant solutions interoperability.

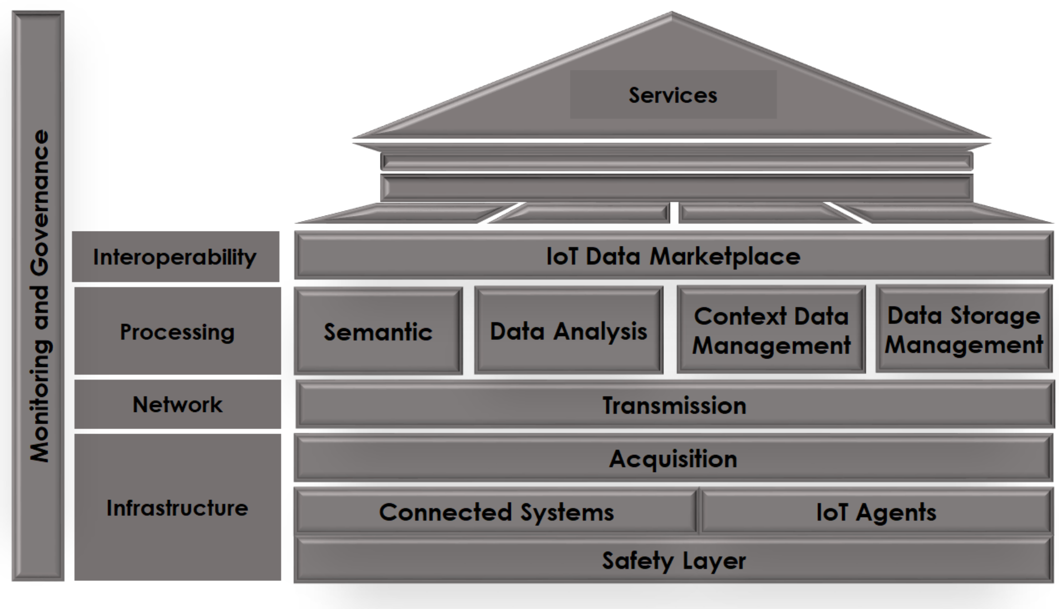

Fig. 1. Proposed generic architecture.

A. *Infrastructure Layer*

The infrastructure layer describes all the required utilities, devices, sensors, facilities, as well as the sources and its indicators. The infrastructure supports all the services, transportation, and environmental, as well as governmental aspects. Moreover, networking infrastructure is one of the compulsory components which configuration should be compatible with the predicted participating items. The network configuration could be considered one of the most critical aspects in the construction of smart cities.

1) City sources components and indicator: Many vital components which could be successful key aspects in smart cities are discussed earlier [17] (Fig. 2). These components are demonstrated in this section with discussing their effective contribution. The following points discusses each component, its standards, perspective, and contribution to the smart cities' paradigm. It is worth highlighting that although this section discusses each component individually, however; practically speaking; these components are interrelated. Therefore, a component could be discussed in various places in this section.

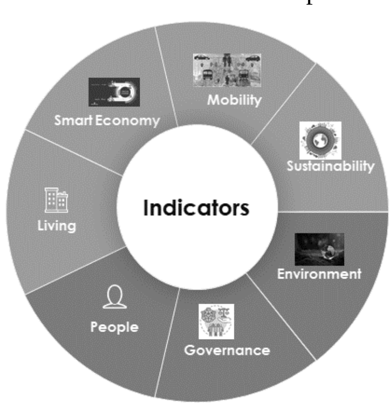

Fig. 2. Smart city indicators.

a) Smart Economy: Smart economy is achieved by incorporating a set of features into the economy such as innovation, digital transformation, sustainability, and high productivity. Smart economy focuses on the level of quality and standards of life which is evaluated by a new set of variables including basic needs, community participation, technology advancement, and scientific aspects. The concept of smart cities is multidimensional dynamic as well as adaptable. It includes economic, social, and motivating individuals' aspects. There is an immense need to balance between the current and next generations. Therefore, the focus of developing the current generation could result in identifying the effective methods and polices for development while maintaining the required quality with continuous quality upgrading. Smart economy concept leads to a clear identification to the relationship between the value of the economy and the satisfaction level such as the employees' satisfaction, customers' satisfaction, etc. it is also related to the level of availability either products or services with the satisfying quality. Therefore, the bond between smart economy and scientific research is vital which could be the key success to achieve such targets. A society that adopts the concept of developing its knowledge succeeds in raising the intelligence level. With efficient management, the goal becomes a fact.

b) Mobility: Most researchers focus on mobility with the aspect of traffic. Although this is one of the most crucial factors, however, it should not be the only mobility focus. Mobility is a crucial factor for emerging smart cities. The main discrimination between mobility and moving to smart mobility resides in general to the ability for easy access to the required information in a real time manner. The information continuous availability and easy access genuinely leads to improving services, saving time and effort, as well as raise the satisfaction level. Main factors that initially affect mobility could be the success in developing sustainable plans, identifying measures to reduce conjunctions (for example, reduce number of simultaneously moving cars in the city), a successful management plan, and deploying alternatives for the services. Focusing on the mentioned example, one of the vital factors for reducing the number of cars is the online information availability without the need to move to the information source. This could be highlighted as a clear example for the effectiveness of the real time management system.

c) Sustainability: Sustainability is a crucial factor for smart cities which is in focus for many researchers. Most of the researchers' objectives are to reduce energy consumption and CO2 emissions. The balance and economic usage of energy sources are also effective for sustainability. Moreover, seeking optimal sources' usage, developing a green environment, recycling, intelligent grid management, and developing supportive policies to reach these goals are also different pillars for efficient sustainability. For example, water sources management sustainability is challenging which could be achieved through intelligent technologies such as IoT technology.

d) Environments: Transforming to smart environments is a significant factor for smart cities. Green environment, water margins, controlling gas emissions, controlling wastes, and efficient energy management are some of the smart environment-affecting factors. Different intelligent solutions could be proposed. Gasses emissions prediction could contribute to gasses control which also leads to maintaining a green environment. Gasses emissions prediction is related to monitoring different activities such as traffic. As mentioned earlier, these factors are interrelated, therefore, in this example, it is clear that smart traffic systems could lead to minimizing the gasses emissions.

e) People: As smart cities main aspect is increasing the quality of life, therefore, People are considered the core factor of smart cities. They are the main players who have the benefits of the offered services and devices. Living in smart cities requires people to accept and be able to utilize this environment. On the other hand, securing people privacy as well as facilitating the usage of offered services are two of many factors that lead to the required level of acceptance. Educating people about the smart cities aspects is another factor. Their growing knowledge of how these services facilitates their lifestyle reduces their risk level and raise the level of trust. One of the emerging educating sources for smart cities is the social networks. Since connection is the key aspect for the concept of smart cities, therefore, considering all communicating channels should have given attention. Social communication among people should be utilized to exchange experiences and share opinions. Moreover, sharing resources, data, and benefits could also be intelligently performed with maintaining people privacy. Smart people as a main pillar of smart cities should not only share services, but they should also share data and knowledge targeting to ensure long-term benefits. For example, sharing data and knowledge about the city roads may lead to more enhancement in the roads infrastructure which leads to enhancing the traffic services. Smart people should have skills such as being easily adaptable, accepting creativity, flexible, ability to participate in the community, able to identify their goals, as well as having knowledge about the rules.

f) Living: Smart living is comprised of the living in smart surroundings including smart buildings such as smart educational institutions, smart healthcare system, and smart tourism services and places. An example of the facilities that facilitates smart living in houses could be the contribution of IoT in home appliances, voice commands, and others. IVR is proved to be one of the useful solutions for smart living, especially being easy to learn and access. Different focuses have been performed to many other contributing systems to smart living such as healthcare system which is a non-negotiable one of the most vital systems in the community. Real time monitoring systems could contribute to various aspects such as healthcare, transportation, educational, and many other systems. Such innovation in the different business models reflects the required levels of management, leads to a high-quality level, provides a high value for the cooperative environment and contribute with a high impact for smart living concept.

g) Governance: The government is the core vital barrier that is able to promote smart cities concept to the people. The success of smart cities relies on the success of the government in providing the smart services, maintaining the relating channels, issue the suitable laws and regulations for maintaining privacy, fair facilities usage, and other aspects. E-government services should be one of the investment targets targeting to contribute to prosperity, satisfaction and enabling organizations. As the impact of social networks is already mentioned, governments could utilize such active sources as an effective strategy to motivate people in contributing to the smart cities concept. Achieving such a goal also relies on the success of maintaining security and privacy. Although technological aspects are key factor for e-government, however, managing policies are also vital to enable people to use the offered services but with regularities. Different metrics could raise the level of trust between the government and the people including the services effectiveness, citizen engagement, the process transparency, and the clear collaboration. Sustainable governance could be supported by effective environments such as cloud computing systems. This environment could heavily support the success of such framework due to the continuous engagement, communication, and collaboration.

2) Safety Component: Smart cities platforms need to maintain security requirements for both services as well as data. However, supporting security could be performed in a flexible environment to accommodate the needs' variations. Users' integrity, accounts' authentication, confidentiality, and trustiness are required for maintaining the platform protection as needed [18] [19].

a) Protecting Data Privacy: The privacy protection for all levels of data should be addressed starting for the lower level represented in the infrastructure of the proposed platform to the higher level representing the offered applications for the people. One of the main methods is encryption. Encryption supports securing data while migrating as well as while residing in the physical data repositories. It is also vital to support the system against breaching by unauthorized users. Therefore, security procedures should be clearly defined and maintained on a regular basis. This task is a non-trivial task since data providers and consumers may engage with third parties to access data sources. Therefore, polices should be professionally managed for the success of controlling the access of data and its sources. All the contributing parties should comply with policies that maintain data privacy.

b) Devices Privacy: The variety of the services contributing to the smart cities leads to an impossible situation of identifying a unified security method for all devices as each device has its nature and capabilities and requires its own security procedure. On the other hand, balancing the equation of securing the contributing devices on one hand, and reducing resources consumption on the other hand makes this task more critical. Smart cities system should provide end-to-end system for security; for example, starting with the API level for IoT devices; moving forward to apply authentication and integrity methods. The boundaries of such critical systems should be governed by a set of policies and the boundaries should be clearly identified.

3) Sensing Component: Sensors have a key role in smart cities. They gather data, then transfer this data to its corresponding objects. This data also moves through the network layer to the cloud in an agile manner targeting to a fast response and immediate message passing for reply. With the expected network load, several paradigms could participate in the framework to avoid congestion. Load balancing techniques could be utilized to avoid network servers' overload. Data handling and resource allocation algorithms could be utilized with a cloud monitoring system for homogenous resource allocation. Resources allocation and task scheduling techniques support the assignment tasks in the application level which ensures a prominent level of service quality. Moreover, the dynamic computation complexity at the sensors level should be considered to ensure resource provisioning.

4) Connected Systems (IoT Management Agent): The main idea of the IoT paradigm is enhancing the working processes through the ability to receive instant services that are transformed from physical objects in a real-time manner [20]. IoT is basically a communication between objects either these objects are machines, utilities, devices, or human. RFID, sensors, and embedded systems are the main players in the IoT system. It is a fact that IoT paradigm is one of the most challenging evolutions in digitalization phenomena. This evolution has moved the field of digital business into a new level of competence, efficiency, and effectiveness. IoT offers an improved business models with the ability for cost reduction.

The current architecture for IoT systems suffers from the lack of agility for services. This situation highlighted the idea of embedding the agile concepts and practical aspects into IoT systems architecture [21]. Agile strategies support business processes with maintaining optimization in a real-time management manner which consequently supports many opportunities to successful business solutions [22]. The current framework proposes a flexible agile-based IoT architecture which helps in the ability to accommodate with the dynamic environment of the smart cities. The proposed architecture considers the database security over the cloud environment with the availability for end-to-end access under the agility umbrella for more efficient computation and ensure high scalability to ensure leveraging the resources allocation. IoT platforms perspectives either focus on the objects or on the internet, the proposed architecture adopts a modular perspective targeting the services quality with maintaining agility for higher satisfaction rate.

It is a fact that technologies emerge quickly which requires continuous adaptation in a fast and flexible manner. The proposed framework has loosely distributed components to provide a flexible approach that permits components replacement with nearly non-impact to other components. Following the proposed approach minimizes the risks associated with the traditional IoT architecture deployment and ensures the multi-operating machines with maintaining the working scale. One of the fundamental aspects for the proposed framework is the concept of encapsulating the development issues and its capability of integration flexibility of trusted services with establishing the sufficient data repositories that have common basics for the smart cities. The proposed architecture ensures having a reliable scalable system with future adaptation capabilities. The recommended platform should have vital specifications to ensure the digital connection between all systems as well as ensure the high system scale with maintaining privacy and security. The factor of the platform interoperability and trustiness ensures the system stability with addressing the economy benefits from different perspectives.

The proposed architecture (in Fig. 1) illustrates the main components in a layered approach with demonstrating the corresponding standards. The following principles have been taken into consideration.

- The proposed solution is suitable for large, medium, and small cities based on its simplicity and adaptation availability.
- The verities of deployment solutions could be applied by the proposed architecture.
- The main international standards have been considered.
- Common features have been presented to ensure the generality perspective.
- Modular approach to ensure the architecture technology adaptation.
- Enabling interoperability by employing open API with semantic data interpretation.

5) Acquisition Layer: This layer considers gathering the required data from various sources. Data streams are produced from edge devices, it is then processed on the go during migration through the network to avoid delays. The process involves the physical devise which is the closest to the determined data source and is responsible for the basic aspects of data processing and primary analyzing data. The analysis results are then migrated through the shortest channel with the real-time conditions to boost the cloud center for the data and initiate the decision-making alternatives.

B. Transmission (Network) Layer

The network layer provides the required support for both data and applications. The associated network servers and the sensors manipulate the data starting from gathering to processing over the cloud environment. The network layer task is to maintain this process quality including the delivery time and ensuring the satisfying of the business requirements with the required performance. This situation raises the need of embedding the agility concept in the network architecture especially for the IoT architecture. Network infrastructure sensors' task is continuous monitoring and recording the parameters. Detection stations keep collecting data as active nodes for all conditions such as weather, power, chemical, and other data.

To achieve the required goal, several requirements should be accomplished. The network should be able to provide the available services to multiple tenants. The network scalability should be of acceptable level with respect to the number of players and devices, traffic scale, bandwidth and other parameters. Most of the entities require either L2 or L3 VPN with security approaches for IoT devices such as isolation. Services should be continuously available to all players and contributors; therefore, the network should adopt the redundancy approach at all the network layers in order to avoid possible failure at any time and ensure instant re-convergence. The contributing devices should have the ability to tolerate under the extremes of the environmental parameters. To accomplish successful operations and other previous requirements, it is critical to adopt simplicity in the network operations.

IoT allows disseminating information for the purpose of enhancing business processes. A continuous communication between the participating machines in the network is performed through the IoT devices. Related technologies such as RFID, sensors, and embedded systems need to be critically selected for higher scalability. Engaging IoT for smart cities ensures productivity, safety, and quality. However, the traditional systems are lacking agility in supplying the system services. Therefore, introducing agile manifesto into the IoT system provides a real-time adaptation to the devices' management process, ability for optimal execution, and ensure optimizing services. The interconnectivity between IoT and agility provides the smart city architecture with massive successful opportunities. Introducing agility with its main concepts of simplicity, flexibility, adaptation ability, incremental approach, and refactoring provides an opportunity for continuous adaptation for the business services with ensuring high competing level. Leveraging the agile environment for IoT with the cloud platform is a triple based approach for smart cities which can provide high performance services for people. In the proposed approach, the internet based IoT approach is followed as the main focus is to provide scalable services for users.

In order to highlight the advancement of agile based IoT in smart cities over traditional IoT systems, the following points could be highlighted. Usually, the devices are connected through the sensors with transferring the data and readings. By embedding agile-based IoT cloud platform, these records are instantly updated through the cloud platform and this update is considered in a timely manner. The traditional system usually suffers from performance issues which hinder the ability to promote the services that has higher demands. The proposed architecture ensures a high performance. The traditional architecture does not adopt defined standards, rather, each pilot project has its own individual standards. The proposed architecture ensures the ability to adopt the same standards and ensures the concept of universal standardization. The traditional architecture suffers from excessive cost as a high number of supportive devices such as sensors require to be embedded in many places to ensure good coverage and continuous communication. On the other hand, the proposed system extensively reduces the cost according to the domination of cloud environment which can be accessed irrespectively of time or place with the lowest communication cost. There are no quality standards in the traditional system while in the proposed system, as agile manifesto is introduced, then following quality standards could be considered as one of the main parameters on focus.

C. Processing Layer

1) Semantic Component: Integrating semantic concepts into smart cities platforms is one of the emerging approaches [23] [24]. IoT services that are based on semantics are introduced in some research [24]. The research in [25] proposed a method for processing with semantic indexing while in [26], the concept of semantic IoT is introduced but was limited to the IoT applications only. The semantic component is based on multi-level analysis of data and explored knowledge. First level is for infrastructure data, then the data gathered from the IoT contributed devices is considered the second layer, the third layer includes the associations between players through the communication channels, business, social, and other available channels. Embedding the semantic component provide more meaning to the distributed data through the network. Moreover, applying machine learning techniques could contribute to enhancing the data quality through avoiding the data sparsity, outliers, and other data challenges. Machine learning techniques are well known for their ability to successfully deal with such challenges [27]. Semantic component deals with data in a collaborative environment. Data relationships are explored by stamping these data with the semantic annotations representing the relationship nature, time stamps, the defining factors explanation and others. Feature connectivity and weighting also contribute to the semantic explanation process [28]. Semantic components are responsible for providing meaningful explanation. For example, if a request for traffic in a certain territory is initiated, then the data is collected, aggregation is applied from various sources layers, and a virtual entity is created. The features vector is explored, and the answer of the user query is provided through the predicted result.

2) Data Analysis Component: The data analysis component utilizes a set of models for processing data. A model repository should be included with a supportive architecture for identifying the suitable model for each received data. The model set could be divided to various categories such as statistical, learning [29], optimizing, forward and backward sensing, and forecasting. The availability of a variety of models highlights the opportunity for the analysis of different data nature with various levels of complexity [30]. The selection of the suitable model is based on the user requirements, the available data, and the purpose. The main goals of the data analysis component are to identify the exploration process that enables a selective set of data models to support both systems and applications interoperability between the interrelated communities. Moreover, classifying the available data models according to sectors and interoperability ability is on focus. Replicable models are accepted, even recommended for different sectors. Additionally, the higher capability of data volume manipulation that data models could consider provides a higher level of trust. This supports the system applications to reach their requirements and ensures higher efficiency and effectiveness. The different data models can play a communication role among different communities. Therefore, one of the main success factors is the clear and well discrimination of different data models manipulation methodology as it provides a level of trust for data migration among communicate. Moreover, as different data formats and structures are usually required by different application wither structured, semi structured, or unstructured data, therefore, a variety of different analysis and storage methods for different data sources formats as well as introducing analysis methods for data formats transformations could provide successful support.

3) Context Data Management Component: This component provides a set of management plans for data. These plans are initiated according to the integrated data and the different comprehensive understanding perspectives to the data. Understanding data is accomplished through gathering data from various sources, integrating these data, applying methods for semantic data explanation which context is received from these sources. The meta-data supports the comprehension task according to the associated entities and their functionalities. These entities gather events and migrate these events' data for the required explanation. The required pillars to perform this process efficiently is the data availability, accessibility, usability, and sharing ability. This component is an enabler for the applications to be able to explore their relevant data and be able to apply enquires over this data. Although the heterogeneity and diversity of data could be an obstacle, however, the structured architecture of the integrated data lakes enables the data migration among different applications. Context validation should be also applied to confirm the operability and data validity.

4) Data Management Component (Agile-based component): Management of data is accomplished through an identified standards API. This direction provides the ability for the re-using facility as there are common solutions standards. The ability for re-use also ensures blocking the lock-in issue which consequently sets the availability for continuous monitoring and improving ability. The re-use ability could also be supported by presenting a common taxonomy which is pre-identified for the data and the services which directly leads to ensure standardization. Tracking the updates is accomplished through the identified APIs which supports the access simplicity, resources accessibility while avoids issues of inconsistencies.

5) Data Storage Management Component: The aim of this component is to provide continuous and easiness in the data access ability through the services that are supported by AI technologies [31], IoT devices, and communication channels. This architecture provides an easy low-risk environment for data access through contributed cities. As digitalization is already established universally. One of the keys for successful data storage and migration is the ability to ensure the continuous accessibility to the data sources with nearly zero-risk through the infrastructure's owners. Then, re-using and sharing data provides a healthy environment for the different applications for common solutions, fair competition, minimum risk, and consequently supports sustainability. One of the key issues is the data privacy and security which is crucial aspects. Data usage agreements should be established. Consequently, this enables the required communication among providers and consumers and facilitates ensuring the prevention of data misuse and protects data flows in the system. However, the contributing entities should be able to control their data accessibility and valid process.

On the users' level, managing data is accomplished through their own controlling attributes. Users set their own rules in sharing their data, services, or applications. Trustiness is one of the key aspects for personal- management. Users have their security credentials which enables them to protect their data from others including infrastructure providers. Users have their right to set the access level and scope for others, manipulate their own data and use the agreement when needed. Users' authentication is a critical aspect to consider. Each user must have his own credentials. Cloud environment is known to be a flexible easily accessible system in general, however, data could reside in an on-premises cloud based system to ensure the required data protection. On the other hand, thin/thick client-based cloud architecture could also provide the balance between flexibility, accessibility and privacy.

D. Interoperability and Layout Layer (IoT Data Market Place)

Expanding the system scaling should be available as the more users intervening the system or the more devices contributing to the system resulting the raising of data streaming. To successfully manage the increase in data scaling, additional network nodes should be added according to the need. On the other hand, additional storage repository and additional memory should be on focus to satisfy the increase in the computation according to the new requirements. One of the key aspects is the ability for the community contributors to have access to the system resources and be able to perform their needed functionalities, therefore, agility paradigm could be one of the main successful key aspects to satisfy this requirement. Moreover, as the contributors in the IoT system is the devices, sensors, and the gateway, the communication between these parties can be accomplished through many paths with different standards and protocols. Flexibility is required for updating the platform contributors, communication patterns, and possible changes. Communication patterns could be one-way from the devices to the gateway, information requests from devices, transferring messages through the system, or accomplish a determined task by one of the devices.

In order to ensure the architecture success, there is an immense need to ensure some factors such as interoperability, easiness, usability, and availability. As proposing a good design is one vital factor, however, this design should be efficient and effective for successful operation. Entities have their own data and naturally use different data models and different methods to process this data. Therefore, the need for unified standards has become critical. Interoperability is supported by applying public network standards and open protocols which organize the flow of data and information through gateways and APIs. The data and information migration between the network components should be according to these protocols and set agreements. Accordingly, new contributors could easily detect these gateways and APIs, and the integration is performed with the required agile approach. Accordingly, practicing such environment should be easily performed.

Pivotal points identify the Setting the system pivotal points should be intelligently established to connect between the constructed smart city system and the external environment as well as the system components themselves including devices, sensors, and the different smart management systems such as traffic, e-market, and others. It also controls the data migration through the system. Successful identification of the pivotal points supports the concept of reusability wither within the system on focus or other similar systems. Concrete identification of the level of coupling in the system is critical, from one hand, tight coupling is secured but hard to change and higher expectations for failure while from the other hand, loosely coupling systems is more flexible but high securing risk. Pivotal points could contribute enable integration of the different architecture components.

E. Applications (Services) layer

This layer provides the set of services and applications to the individuals. As discussed by much previous research, various applications have emerged such as smart grid, smart transportation, smart environment, smart living, smart health, smart energy, and others. Significant obstacles have emerged in the offered smart city applications. For example, the service provider can illegally access the data of the people living in smart cities such as medical or financial data. Moreover, smart mobility can use different techniques to detect the users' patterns which could expose users to risks. This situation arises the vital impact of safety component and highlights the immense need for providing the protection layer over both data and application layers. The applications quality by logic depend on the quality of the previous layers, however, the enhancements of the services relies on a set of pillars including the ability of integrating services, how users can depend on these services, their quality level, ability for expansion and updating, and the services' standardization level. The evolution of embedding agility to the provided services can raise the guaranteed level of these services as it ensures higher performance and consequently higher satisfaction.

F. Monitoring and Governance Layer

Continuous monitoring should be performed to confirm the applicability and continuous operating to the smart cities' architecture. Identification of all contributors either people or devices should be clearly accomplished. Moreover, on the user level, a clear monitoring of the user activities and even expectations of his future activities should be performed. As this is a key success factor, however, it is not an easy task to perform. Several intelligent machine learning, data science, and artificial intelligence techniques contribute to this task in order to be successfully performed [32]. The concept of governance is applied to both data and applications. It is not considered on simple management tasks, rather, it is considered about providing a procedural action of continuous protection and tracking [33]. The following factors should be continuously monitored.

Resilience, failure could occur to devices, applications, or network components. Therefore, a self-healing system is recommended to avoid failure complications and ensure resilience. Self-healing includes many procedures such as adopting redundant links, continuous monitoring to IoT devices and the interaction between different components and users.

Performance, the system performance should be maintained through guaranteeing the instant response to the real time users' interaction. Applications should be continuously available and efficiently responding. Continuous automation to testing scenarios should be applied. Moreover, upgrading plan should also be on focus. Licenses should be available and complete authorization is expected.

One of the main factors is the feedback monitoring and recommendations to various aspects in the architecture. This has become a well-known principle for enhancements and avoid acceptance failure.

G. Enablers of smart cities

Several factors could affect the progress of smart cities implementation, some of these factors are discussed in this section (Fig. 3). Governmental support is one of the most effective enablers for smart cities construction. The government should be able to remove any arising barriers that hinder this change. Sustainability is another enabler which support the continuous development with the ability to gain public trust and economic stability. Approaches recommendations availability to reduce change resistance is another enabler. Fund availability is one of the critical enablers to be able to provide the requirements of constructing smart cities. Agility adaption in the digital environment of management, marketing, and other services with courage in adopting the change could provide more innovations and the required changes could be accomplished with minimal risk.

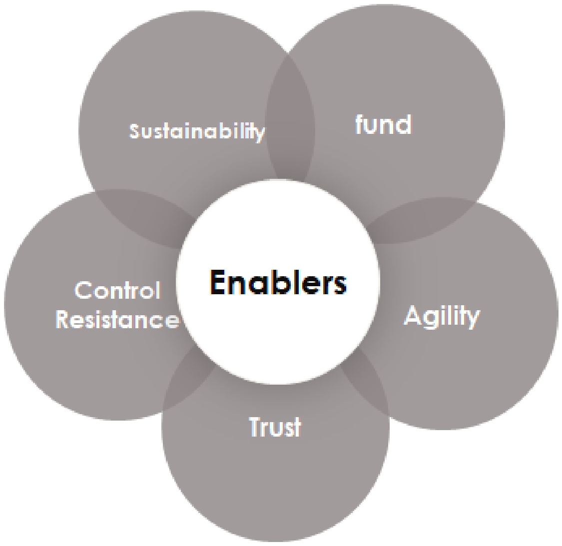

Fig. 3. Smart city enablers.

H. Challenges on focus

There are different challenges directions that should be highlighted. First, the data sources and formats heterogeneity as it is collected from different data sources. Moreover, data characteristics such as velocity, volatility, variability, veracity, and value should be determined and evaluated. The method to exchange the required knowledge by the players should be intelligently performed. Storage repositories access could be one of the major challenges in the platform especially for the governmental assets. Data standardization is another challenging aspect with the storage diversity. The construction cost debate with the return on investment is challenging as most of the return aspects are quality perspective. Ensuring the new paradigm acceptance by the users in the cities who are represented in the citizens should have a robust plan and complete governance support.

V. Applications Sample Model

A vast set of domains has seen the development of intelligent applications. These applications are not yet widely accessible; however, initial research suggests the potential of IoT to enhance the quality of life in our society. IoT applications are utilized in home automation, fitness tracking, health monitoring, environmental protection, smart cities, and industrial environments. Focusing on residential automation as a sample, smart houses are gaining popularity nowadays for two reasons. The sensor and actuation technologies, together with wireless sensor networks, have substantially advanced. Secondly, contemporary individuals exhibit trust technology to mitigate their concerns regarding quality of life and home security (Fig. 4).

Smart homes utilize an array of sensors that deliver intelligent and automated services to users. They facilitate the automation of daily routines and assist in establishing a routine for persons prone to forgetfulness. They facilitate energy conservation by automatically deactivating lighting and electronic devices. Motion sensors are generally employed for this purpose. Motion sensors can also be utilized for security purposes. An intelligent agent is offered that employs diverse predictive algorithms to do automated chores in reaction to user-initiated events and adjusts to the residents' routines. Prediction algorithms are employed to forecast the sequence of events in a household. A technique for sequence matching preserves event sequences in a queue while simultaneously recording their frequency. A prediction is subsequently generated utilizing the match length and frequency.

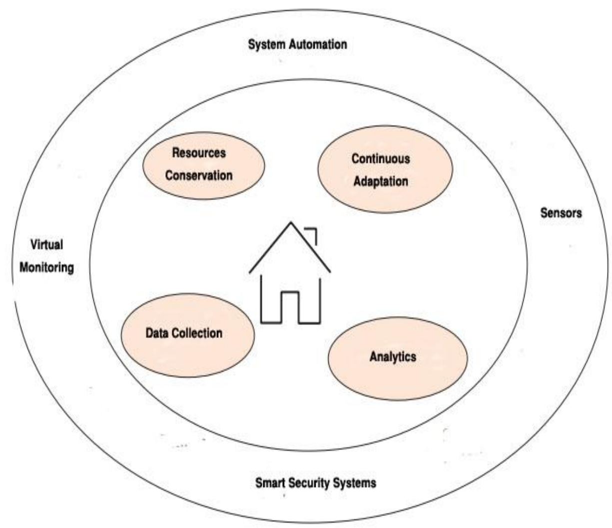

Fig. 4. A proposed block diagram of adapting smart home system.

Other algorithms employed by analogous applications utilize compression-based prediction and Markov models. Energy conservation in smart homes is often accomplished by sensors and contextual awareness. The sensors gather data from the environment, including light, temperature, humidity, gas, and fire incidents. The data from diverse sensors is transmitted to a context aggregator, which relays the gathered information to the context-aware service engine. This engine chooses services according to the circumstance. An application can autonomously activate the air conditioning when humidity levels increase. Alternatively, in the event of a gas leak, it may extinguish all the lights. Smart home applications are highly advantageous for the elderly and individuals with disabilities. Health is checked, and families are promptly notified in crises.

The floors are fitted with pressure sensors that monitor an individual's mobility within the smart home and assist in identifying if a person has fallen. CCTV cameras in smart homes can record significant occurrences. These can subsequently be utilized for feature extraction to ascertain the underlying phenomena. Fall detection applications in smart environments are effective for identifying instances where elderly individuals have fallen. Fall dynamics is identified by evaluating motion patterns and also detects idleness, comparing it with previous activity levels. Neural networks are utilized, and sample data is sent to the system for various categories of falls. Numerous smartphone applications are available that detect falls using data from accelerometers and gyroscopes.

Numerous obstacles and issues pertain to smart home applications. Security and privacy are paramount, as all data on occurrences occurring within the home is being documented. If the system's security and reliability are not assured, an attacker may compromise the system and induce harmful behavior. Smart home systems are designed to alert owners upon detecting anomalies. This is achievable with AI and machine learning algorithms, and academics have commenced efforts in this area. Comparing the sample model with the literature [3, 20, 29, 34], most of the researchers focused on one enhancement direction; including cost, processing, and security; with no ability for a complete vision.

VI. Conclusion

The research proposed a complete generic architecture of smart cities. Smart cities consider allowing both people and governance to benefit from technology. The concept of embedding intelligence into the cities' aspects requires ensuring that the entire process could be altered. One of the main pillars is the data availability for the required level of quality and sustainability. Therefore, the proposed architecture presented all required aspects for a complete transformation to the digital smart city including infrastructure, processes, data management, players, roles, enablers, and services. The research highlighted the enablers for the architecture as well as the SWOT analysis for implementing the proposed architecture. Finally, challenges for the transformation process are discussed. It is expected that the proposed smart city architecture is encouraging and could move the field from the pilot individual projects to the standardization model which consequently provide a universal perspective to the smart cities concept rather than having different understanding to the same concept in the pilot projects. A main future consideration is to apply the proposed architecture and evaluate the transformation process in a real-life example. Another future direction is to provide more details and recommendations for practical development to each component.

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