



This paper has been structured as follows. The next section discusses significant challenges and provides a brief overview of network architectures and key concepts to make the following sections more readable. In the proposed architecture section, a new architecture has been introduced. Then, the contribution along with its simulation details has been presented and evaluated with the obtained results in a separated section. Finally, the conclusions and challenges for future work are discussed in last section.

## II. CHALLENGES AND ISSUES

In the digital age, human life has become easier because almost everything is automatic. Today, the Internet has become an integral part of everyday life, without which life is impossible. A smart society is a society with a conscious effort to use information technology in life and work. Communities tend to use smart systems to be able to provide efficient and advanced services to citizens, to develop new levels of cooperation, to help governments meet big goals, and to create innovative business models. This research can be done in the field of smart education, smart parking and smart rooms, etc. The review and studies of previous research in this field has been used as a research method related to the subject to design a new architecture for the smart universities.

### A. Network Studies Challenges

First, four research categories are defined for this field: system level, network adapters, network level and connection level [5]. Important research highlights in networks include network topology, traffic control strategies, switching techniques, data flow control patterns and routing algorithms. Figure 2 shows the classification of network research.

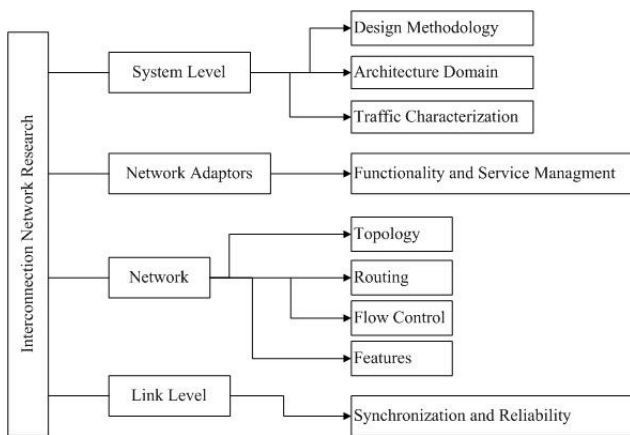


Fig. 2 Classification of Network Research

Then, based on related works [6, 7, 8], developed network performance depends on the architectural features and communication properties. Many studies have been done on this important topic. In networks, the topology is an architecture of different components, including nodes and connection links [9]. A network node consists of the structure of a switch and a source. Switches must be fast and

energy efficient because the network plays a vital role in determining performance and integrates many computations [10].

Currently, various studies present several new architectures that are enhanced by old network architectures [11, 12]. Mesh and Torus as a direct architecture are among the most popular topologies in network architecture. Torus network has a regular architecture with low diameter and easy scalability; however, Mesh presents an architecture with low complexity and high diameter compared with other network architectures. The simplicity of these two architectures made them more high-ranking. However, the existing problems indicate that they have not improved performance in terms of communication delay.

### B. Smart Studies Challenges

In designing the architecture of smart university networks, the change of global population in terms of network bandwidth, delay, scalability, and data security challenges, increase pressures on different areas of the university. Because in the near future, technology can recommend the best quality of life to finance everything through smart living, smart energy, smart transportation, smart mobility, and smart business models. This development will result in smart universities as well. Here we discuss some of the challenges of network architecture in [13] that must be considered for a sustainable network .

- 1) **Low latency and high mobility:** It is introduced because of the services that are requested simultaneously by several devices at various places in the smart university. So effective network architecture is needed to address these constraints by smart university programs.
- 2) **Structural scalability:** It is second challenge for the smart university network that we must address as soon as designing a sustainable network architecture. This feature allows the system to develop as needed without major changes in its architecture.
- 3) **Network bandwidth constraints:** In smart university application scenarios, due to the limitations of network bandwidth, centralized architecture-based solutions are not suitable. All the collected data are sent to the main network in a centralized architecture, while requires a lot of network bandwidth. To reduce bandwidth usage and overcome the bandwidth limitations, we require proposing an architecture that allocates data to be processed and analyzed locally. Only clarified data will be sent to the leading network if it was necessary.
- 4) **Privacy and security:** By increasing of the connected devices to the Internet, the smart university's network infrastructure creates several privacy and security challenges. Thus, the architecture of smart university networks should be able to keep information contrary to change, exposure, illegal access, and cyber-attacks.
- 5) **Single points of failure:** The architecture of the smart university network have the considerable single failure points because of the continuous growth of heterogeneous networks. It can reduce the services provided for the smart university. It requires a tamper-proof structure to

provide a fault-tolerant network for smart university network applications.

### III. RELATE STUDIES

In years, many features of networking have been the subject of much research. A network definition is motivated by the network architecture and its routing strategy to influence network performance [13]. To our knowledge, studies on smart networks are very limited to date. Most work focuses on using IoT<sup>3</sup> in a wholly general or specific way. Designing a new network architecture takes into account all features of present and future challenges. We review these issues in related studies to increase our knowledge of the latest network studies.

Concerning previous research, widely used architectures by networks have been reviewed in recent years. The main challenge for proposing them are interconnection architecture. Reviewing the latest studies showed the current architecture have been designed to address the network performance improvements in terms of short delay and high throughput. Kim et al. [14] introduced the concept of global distribution and centralized local management to achieve scalability and efficiency in IoT management. Baga et al. [15] recommended a decentralized platform for IoT in industry to eliminate trusted intermediaries and create a peer-to-peer network. Christidis et al. [16] reviewed blockchain programs and smart contracts in IoT. Jia et al. [17] suggested sharing medical data among cloud service sources. It provides public medical data in cloud storage and allows auditing, data generation, and control of public medical data. Lee et al. [18] presented a safe energy exchange system for IoT. In [24], a communication protocol for the proposed smart city topology using beam sweeping technology and an architecture for internet to everything communication with different entities in the city. The studies in [25] discuss the primary concerns in the complex query process, infrastructure, influencing factors, and challenges for the topology discovery process. G. Tarnaras et al. [26] proposes a better usage of Link Layer Discovery Protocol by taking advantage of existing hardware capabilities to construct a dynamic and automatic topology discovery algorithm while it extracts information directly from the data plane to the control plane. VinuezaNaranjo et al. [27] presents a Fog smart city network architecture (FOCAN), which is a multi-tier structure that the applications are running on things, route, and communicate with one another through the smart city environment. In [28], a CIoT-based smart city network (CIoT-Net) architecture has been introduced. They described how the gathered data from smart city applications could be analyzed using cognitive computing. Paradip et al. [29] proposes a vehicle network architecture based on blockchain in the smart city (Block-VN), which is a reliable and secure architecture to build the new distributed transport management system.

Based on the latest studies above, we explored current architectural challenges to achieve a sustainable smart university network. A new network architecture should

overcome the current limits of smart network architecture using the emerging power of software-defined network (SDN). SDN is an approach in networks to manage network services through a higher level of abstraction. This is done by separating the system that decides how to route traffic from the underlying system that is tasked with routing packets to the chosen destination. SDN architecture is a manageable, cost-effective and adaptable architecture that seeks to be suitable for high-bandwidth applications. This idea is proposed to implement in universities with the smart attitude.

This paper presents a new hybrid architecture for the Smart University Network using SDN to solve the limitations. We also describe the process of extracting our new architecture in the leading network, and for its potential performance evaluation; simulation study is achieved based on the various parameters in the following sections.

### IV. PROPOSED ARCHITECTURE

At the highest level, a smart university connects devices, applications, and people to create new experiences or services and improve operational efficiency [4]. The primary purpose of the smart places is to share information from objects, including construction, transportation, training, and the consumption of other details of people's lives. In this paper, motivated by the study in [13, 19], we introduce a new architecture using SDN based on folded idea to develop in the universities making these places smart. The key focus of this paper is to apply new architecture and obtained results in terms of the improved performance toward the end. In this section, we present the idea of designing a distributed architecture for the university's management and communication system with its properties.

#### A. Architecture Design

Reduction in delay and superior performance for the networks needs architectures with average distance and short delay. The most popular architectures for networks are Mesh and Torus; however, various architectures have been proposed over the years. One of the latest architecture is  $x$ -Folded TM [19]. It is a folded TM architecture with its applicability and enhanced performance. The architecture of  $x$ -Folded TM topology is based on TM topology [20] except a number of the nodes that are shared from top to bottom. Figure 3 shows the applied  $k \times k$  network based on  $x$ -Folded TM topology in this research where  $k=4$  and can be even and odd or greater in future studies. The specified nodes in this figure are supposed to be representative of the different buildings in the university. This architecture presented here uses the key advantages of  $x$ -Folded TM topology to derive the improved architecture for SDN architectures in the presence of specific traffic patterns.

<sup>3</sup> Internet of Things



Fig. 3 Proposed Architecture for a Smart University

### B. Architecture Properties

In the new architecture, each node performs as a centralized server for specific public infrastructures to offer essential services and reach localization. These policies and access credentials store locally registered entities in their database, helping to reduce delay and reduce network bandwidth.

$x$ -Folded TM as the applied architecture in this research is a simplified one that is folded based on an imagined  $X$ -axis where a node  $a = (x, y)$  is a valid node if  $0 \leq x \leq (n-1)$  and  $0 \leq y \leq (n-1)$ . Along  $X$ -axis, the nodes connecting to node  $a$  are:  $(x+1, y)$  if  $x < (n-1)$  and  $(x-1, y)$  if  $x > 0$ . Along the  $Y$ -axis, nodes  $(x, y+1)$  if  $y < (n-1)$  and  $(x, y-1)$  if  $y > 0$  are connected to node  $a$ . Then, the node  $a = (x, y)$  is removed from the  $x$ -Folded TM if  $(x+y) \bmod n = 0$  or  $1$  or ... or  $n-3$ , where  $x > y$  and  $(n-3) \leq x \leq (n-1)$  and  $1 \leq y \leq (n-1)$ . The key features of  $x$ -Folded TM are the diameter and average distance. As a network with high degree of nodes and large diameter is expensive and uses a very low bandwidth, we have motivated in this architecture and applied it as a great choice for this study.

The distributing feature of the proposed architecture can give the system more flexibility and restrict the effect of attacks even if the node is compromised. That is to say if these nodes are compromised, the effect will be restricted to local domains.

## V. PERFORMANCE EVALUATION

We proposed the SDN based architecture to improve the communication performance of the university's network. The flow chart for the proposed research methodology has been illustrated in Figure 4.



Fig. 4 Flow chart of research methodology

The significant approach is the simulation of the proposed architecture with decreasing delay and increasing throughput. In this section, we simulate the proposed architecture to assess its feasibility. Then, we discuss the simulation environment and results based on the different parameter metrics.

### A. Simulation Environment

To assess performance of our proposed architecture, we have considered two types of network topology, including Torus and  $x$ -Folded TM architectures. The size of the Torus network is  $4 \times 4$  (16-nodes), and  $x$ -Folded TM is  $4 \times 4$  (14-nodes). The simulations have been carried out for 14 hosts were tested between h1 and h14 (farthest route) in this research. The simulated proposed architecture is presented in Figure 5.

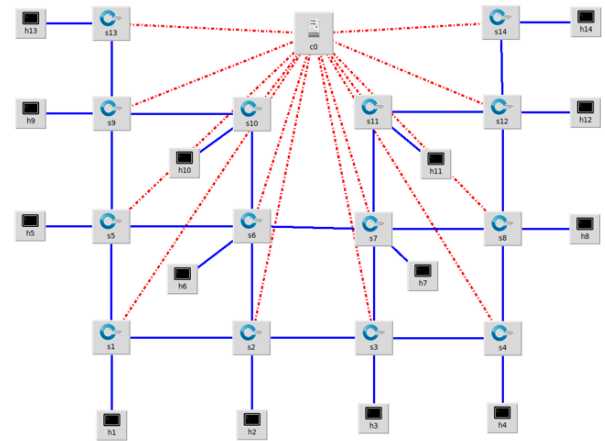


Fig. 5 Simulated Proposed Architecture

We used Mininet to build SDN-enabled nodes. The data stream is sent by D-ITG<sup>4</sup> to produce traffic at the packet level and support both IPv4 and IPv6 traffic generation [21, 22, 23]. It generates traffic at the network, transport, and application layer, includes 300 different simultaneous streams weighing between 1Kbyte to 1Mbyte, and are in the form of UDP packets. These streams are bursty traffic, which means that three hundred streams enter the network at the same time, however, naturally puts a heavy load on the network.

Accordingly, the metrics including packet delay, average packet rate, and packet loss are evaluated. Packet delay refers to the elapsed time for sending a packet from source to destination in the network. Average packet rate refers to the number of packets per second under a traffic pattern through the network. Packet loss is the number of packets that cannot reach their destination. All these metrics are compared with the basic architecture and presented in the following section.

### B. Evaluation Results

In the presented results, the dynamic communication performance of various architectures is shown in terms of average delay and packet rate and packet loss percentage. As observed from the results, the vertical axis indicates Packet loss

<sup>4</sup> Distributed Internet Traffic Generator

percentage, Average delay, and Average packet rate and the horizontal axis shows the number of rounds to simulate the architectures in Figures. 6, 7 and 8, respectively.

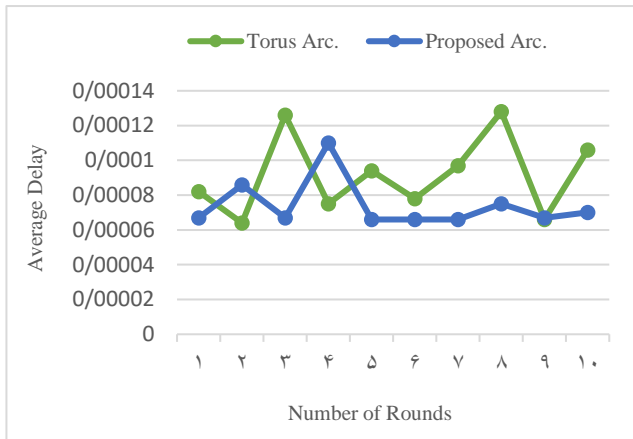


Fig. 6 Average delay in our proposed architecture vs. Torus architecture

Figure 6 presents the average delay of the Torus and our proposed architecture. The simulation results for the proposed architecture exhibits more minor packet delay in 10 rounds. It shows that delay is continuously decreased according to the proposed architecture in this study.

We also observed the result on the packet loss percentage for new architecture in comparison with the Torus architecture. Figure 7 indicates how the new architecture affects the percentage of packet loss and decreases the number of lost packets drastically. The packet loss achieved in our simulation using the proposed architecture is less than 10% on average, while this metric in Torus is more than 20% approximately.

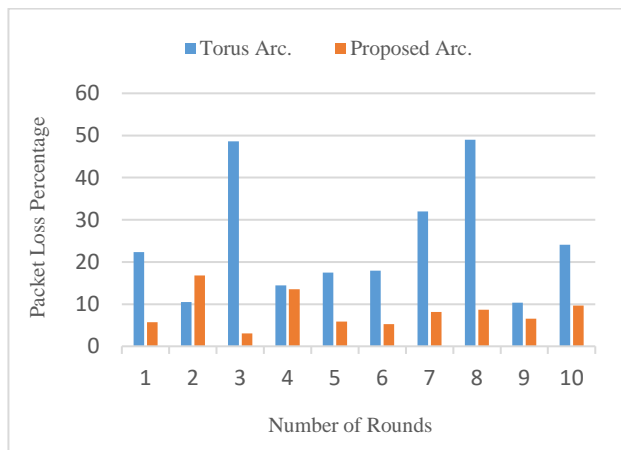


Fig. 7 Packet loss percentage in our proposed architecture vs. Torus architecture

Fig. 8 indicates the results of the average packet rate with two architectures. We can see that our proposed architecture seems more robust and closer to achieving the eligible average packet rate; however, the difference between the two architectures is median for this parameter. Our proposed architecture is more adequate for utilization in smart university applications.

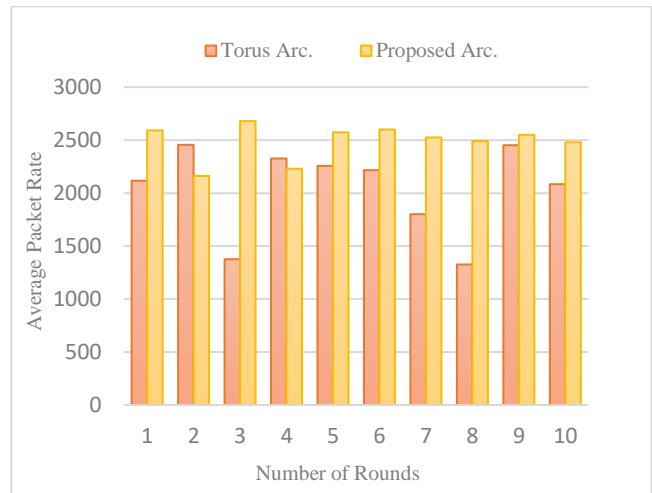


Fig. 8 Average Packet Rate in our proposed architecture vs. Torus architecture

As a result, each graph represented a specific metric in Figures. 6, 7, and 8. The results showed that compared with Torus, our proposed architecture achieved better performance by reducing the average delay and percentage of package loss and increasing the average package rate.

## VI. CONCLUSION

With IoT flourishing, various devices in the environment of smart universities will produce many data. The major challenges of smart studies are reducing bandwidth usage, achieving short delays, and improving security and scalability. As demonstrated, we have emphasized on the drawbacks and developed an SDN architecture for a sustainable smart university network in this paper. We propose a folded topology for an efficient SDN-based architecture according x-Folded TM scheme. The simulation of this architecture is under a bursty traffic pattern to evaluate the dynamic communication performance compared to one of the famous architectures that is Torus. The simulation results presented the efficiency of the proposed architecture. These results reveal that the average delay with new architecture is lower than Torus. In contrast, the average packet rate for the new architecture is higher than Torus. Additionally, the packet loss in the proposed architecture is significantly less compared with the Torus. Overall, it shows the relatively sizeable improved performance for the proposed architecture based SDN.

Despite some limitations in this new architecture, such as the efficient distribution of edge nodes and applied storage techniques in edge nodes, future work to overcome these limitations will begin accordingly. We believe that using the architectural influence proposed in this paper overcomes the limitations of the network architectures; however, a hybrid architecture for a university network with blockchain techniques and this SDN based network will be proposed for future studies.

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