The Impact of 5G on the Internet of Things: Capabilities, Applications, and Deployment Constraints

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Abstract— **The Internet of Things (IoT) depends on communication networks that can connect heterogeneous devices while meeting widely varying needs for throughput, latency, coverage, reliability, and battery life. Fifth-generation cellular networks (5G) were designed to address several of these demands through enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), massive machine-type communication (mMTC), programmable network functions, and support for computing closer to devices. This paper reviews how these features affect IoT system design and applications, and weighs them against implementation constraints. The literature indicates that 5G can expand IoT options, particularly for high-volume data transfer, time-sensitive control, and dense device deployments. Edge computing and network slicing can help match network resources to application requirements. Yet benefits are conditional: practical performance depends on coverage, spectrum, device capability, application architecture, and end-to-end integration. Security, privacy, interoperability, energy use, and deployment cost remain material constraints. The evidence base is uneven: many publications are conceptual reviews or simulations, while few retrieved abstracts report evaluated deployments. The most defensible conclusion is that 5G broadens the design space for IoT rather than making every IoT system faster, cheaper, or more reliable by default. Evaluation should therefore use workload-specific end-to-end measures and compare 5G with alternatives under realistic operating conditions.**

Index Terms— **5G; Internet of Things; mMTC; URLLC; edge computing; network slicing; industrial IoT**

I. INTRODUCTION

In some networks, a single network is required to carry low-power telemetry, and at the same time, the same network is expected to carry the latency-sensitive control or high-throughput video. In previous reviews, it was proposed that issues of device density,

In fact, there are no single connectivity issues, but rather reliability, bandwidth, latency, security, and power consumption are always design questions [1, 2, 3].

An attempt to solve this is where 5G becomes important for IoT, as it offers differentiated services and network architecture that are more programmable. Initial surveys identified 5G as a solution to future IoT use cases' capacity and service-quality issues. Meanwhile, the two types of cellular IoT and LPWAN coexist [1] [4]. Later publications discuss edge computing and network-provided services [5], network slicing for different devices [6], IoT platforms [7], and security and privacy issues [8]. This trend is important because connectivity is just the first link in a chain of sensors, devices, application logic, backhaul, computing, and, importantly, a user.
and governance.

II. EXPLORE METHOD AND EVIDENCE BOUNDARIES.

The first thing to be changed is the way the IoT traffic is seen as a single class of traffic and the beginning to recognize the various types of communications by the type of work that must be performed. The literature typically divides eMBBP into eMBBP for high throughput traffic, mMTC for massive numbers of

low-rate devices, and URLLC for applications where the exchange must be ultra-reliable and time-critical [6, 9, 10]. The rosy claim that 5G is just "faster" is not the case for the traffic of a utility meter, a video phone sensor, and a robotic controller. Moreover, as indicated in the reviews, NB-IoT and other low-power-wide-area technologies are other approaches to achieving devices that are low cost, have superior coverage, and require long battery life [1], [2], [11]. Lastly, even if 5G is possible, these features, such as low terminal power, reliability, and coverage, are still relevant [12] and [13] from the design surveys carried out earlier.

III. HOW 5G WILL IMPACT IOT SYSTEM DESIGN

3.1 A service portfolio for various classes of devices

The most significant conceptual change is from IOT traffic being a single class to the matching of communication to task. An eMBB service for high-throughput traffic, an mMTC service for a large number of low-rate devices, and an URLLC service for applications requiring highly reliable and time-critical exchange represent the three classes of services, which are quite common in the literature [6] – [10]. This “faster” framing is a bit closer to real IoT diversity than just saying 5G is “faster”: a utility meter, a mobile video sensor, and a robotic controller will not need the same service profile. In addition, reviews also refer to NB-IoT and related low-power wide-area solutions as complementary ways to allow devices to focus on other aspects of their design, such as low cost, wide coverage, or long battery life [1, 2, 11]. Previous design surveys also emphasize that, even with the presence of 5G, low terminal power, reliability, and coverage continue to be key concerns [12, 13].

The downside of differentiated service classes is that engineering compromises are not cancelled out. Throughput and coverage, latency, reliability, energy consumption, device cost, and network capacity are all interdependent. The broad surveys identify the following as enabling technologies for 5G: new radio, MIMO, millimeter-wave spectrum, heterogeneous networks, and device-to-device communication, while deployment, power, and congestion issues are all problems that remain to be solved [1], [3], [12], [14]. For now, 5G is not a solution for all low-power or local network applications but rather an expanded toolkit from which radio technologies and services must be selected as appropriate.

Here is a qualitative mapping of the service classes, architecture options discussed above, and their suitability to IoT workloads, but not a performance guarantee.

The following diagram presents a proposed workload-first decision aid: classify the task, choose a plausible connectivity or processing approach, then validate whole-system conditions. It is a conceptual synthesis, not a standardized selection algorithm.

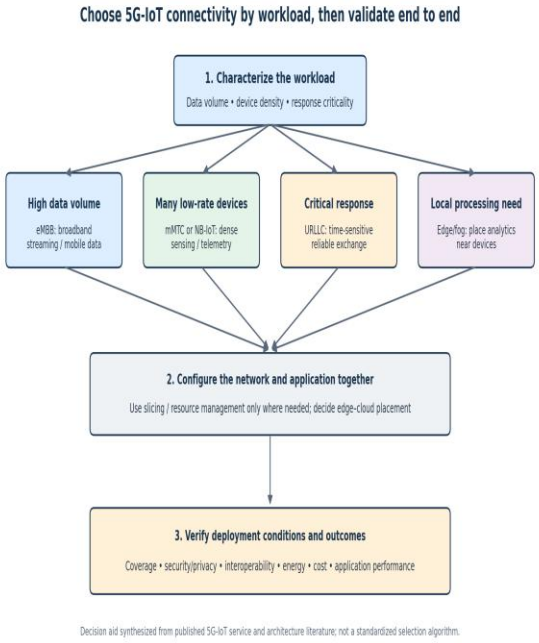


Figure 1: Workload-Based Selection and Validation Framework for 5G-Enabled IoT Connectivity.

3.2 Programmable connectivity, slicing, and edge computing

The potential impact of 5G is not just on the radio link. Network slicing is suggested to be able to provision virtual network resources based on different service requirements, and edge or fog computing can bring some processing and storage resources to the data sources. Their hybridization can alleviate the need to send all operations to a faraway cloud center and can allow for local analysis or control [5], [7], [14]. The concept of network functions virtualization and software-defined approaches is also highlighted as a network management tool in 5G IoT reviews [14], [17], [18]. In addition to this, platform surveys

introduce the concepts of fog computing and cloud-service integration but highlight that decentralized processing and platform design are inherent characteristics of the application architecture and not automatic features of the radio network [7, 19].

Getting closer to the computation may make parts of the conversation path shorter and, in turn, reduce the need for a remote cloud, but end-to-end responsiveness will also depend on the radio access, backhaul, processing, application design, and handoffs. These are simulation results that were presented around 1 Gbit/s for 5G IoT architecture and sub-millisecond latency, not a service guarantee in general [5]. In another paper, computing and storage services provided by the networks and services from 11 IoT platform providers were analyzed, with a clear focus on the impact of 5G on the location of the application services [5]. All in combination demonstrate edge and slicing as architectural possibilities, and there is a need for more comparative field evaluations to find out how much they can do to better specific applications. The system level relation is captured in this schematic, which shows that network capabilities link devices with application services, and performance and feasibility are influenced by cross-cutting constraints [5], [9], [21].

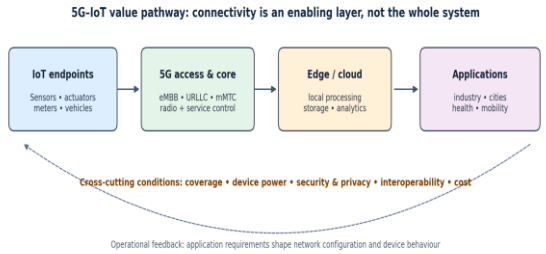


Figure 2: Conceptual Architecture of 5G-Enabled IoT Systems with Edge and Cloud Computing.

3.3 Scale and performance evidence.

Massive connectivity is an attractive proposition, but it's not a measure. The characteristics of a network, such as device density, traffic patterns, mobility, coverage, interference, and access procedures, all have an impact on whether a network can support a particular workload. The research on massive IoT covers the low-power wide-area radio, edge processing, and machine learning-based resource decisions as complementary methods of managing the heterogeneous devices [16]. The transition from initial visions for connectivity to integrated service architectures and application-specific network requirements is also dwelt upon in the context of a wider progression of standards and use cases in work on cellular IoT [19, 22, 23] [1] [13].

The information suggests why headline results of systems should be taken with a pinch of salt. For the proposed 5G-IoT architecture, an example simulation was conducted, and its results showed over 1 Gbit/s throughput and sub-1 ms latency [20]. Furthermore, an example simulation of predictive resource allocation and dynamic slicing has been demonstrated to gain performance in the form of latency and throughput when compared to conventional allocation. The model was shown to have an accuracy of 96.15% in predicting latency and 81.14% in predicting bandwidth [24]. These are not for a 5G pooled case or the average case for 5G. These values are not presented in the abstracts but are crucial for their analysis in a comparison scenario, baseline, traffic loads, and measurement definitions. Current evidence is adequate for the technical feasibility to be established in the particular instances mentioned. It is not yet a typical operating system that is used in the field in IoT applications.

IV. APPLICATIONS: NEW OPTIONS ARE NOT AUTOMATIC TRANSFORMATIONS.

4.1 Industrial IoT and smart manufacturing

Industrial IoT is a good use case, as manufacturing involves a high concentration of sensing, machine coordination, analytics, and potentially time-sensitive control. Edge processing and service differentiation in 5G are associated with remote monitoring, predictive maintenance, robotics, and real-time analytics in the literature [25, 26, 27]. A suggested industrial architecture also correlates eMBB, mMTC, URLLC, and NB-IoT with the requirements of smart manufacturing [28]. Network slicing is identified as a way to prioritize or optimize the resources for various industrial applications, which requires proper configuration and interoperability with operational technology [26, 29].

Of the retrieved sources, one has a concrete application that is not just a capability but a slightly more grounded approach: Meira and colleagues present a system for the industrial IoT that they have

tested on a real shop floor of Bosch Terotechnology, where 5G-enabled devices collect information about the shop floor assets and their environment for an intelligent assistant [30]. It's abstract and does not mention relative latency, reliability, or productivity estimates but does mention that it is implemented in a factory environment and validated. It is therefore evident that in at least one industrial context it is possible to integrate it, but not yet the fact that 5G has brought a measurable productivity increase and that it can replace the copper-based industrial network in every plant. The legacy integration, security, interoperability, and infrastructure are also cited as barriers to the wider industrial adoption in broader reviews [3], [25], [27].

4.2 Smart cities, mobility, health, and agriculture

In cities, the 5G-IoT architecture is suggested for connected transportation, public infrastructure, environmental sensing, and energy management, with the key requirements being the high density of devices and timely data exchange [31, 32, 33]. In the case of transportation and controlled systems, the communication has to be timely and reliable, while for urban sensing it is about the device density and coverage. From the reviewed articles, it is seen that the network, edge processing, and application layer must be designed together to fully utilize the sensed data [14; 34]. These are enabling, not proof points, of the concept of widespread implementation of these services and the irreplaceability of 5G networks. The application of power systems is also included in the context of integrated sensing and control to manage energy [35]. The survey on 5G-supported IoT devices also categorizes services based on the required services and establishes that there is a lack of infrastructure and regulations as challenges for 5G deployment [36]. Another research is focused on the use of 5G-IoT for telemedicine and smart transport [37].

Healthcare applications include data- or time-intensive applications, and remote monitoring applications. While surveys identify potential applications for 5G-enabled medical devices, they also highlight the potential for disruption, privacy, and secure operation of these medical devices [15], [38], [39]. The broader IoT application surveys also include some applications such as smart retail and intelligent transport, besides health and city infrastructure, and it seems that a variety of applications (and not only one flagship application) gives rise to differentiated network needs [10], [34]. An enhanced communication system in itself does not guarantee clinical safety or benefit; these are derived from the whole medical device care workflow and need to be validated by the application. IoT used in agriculture and environmental monitoring can take advantage of distributed sensing nodes and remote monitoring and decision support. According to the literature, smart agriculture is among the listed areas to be enabled with 5G, and low-power wide area network (LPWAN) is also mentioned as an important addition to the low data rate sensors [1], [10], [39]. It's a practical problem, and the high throughput or low latency capabilities of 5G could be used at aggregations points, mobile machinery, or data-heavy applications but simpler battery-powered sensors might be better suited to other radios. The literature reviewed does not reveal a single best technology for accessing agricultural information. In all of these areas, the primary cross-study conclusion is that 5G opens up new opportunities for the range of potential connectivity and processing options. These abstracts do not reveal any general, causal gains in productivity, health, traffic safety, or cost. The claims need to be backed by field testing against the whole system, not just network specs, and must be controlled or well documented.

V. CONSTRAINTS AND RISKS

5.1 Security and trust, privacy and security

The increased number of devices connected and the spread of functions between radio access, core networks, edge platforms, and cloud services increases the number of components to be secured. The architecture, device interaction, privacy, and interoperability are tightly coupled research challenges identified by a security-centric survey of 5G IoT [8]. Exposure to IP-based malware, denial-of-service, intrusion, device security, and standardization challenges are other noted issues in a deployment-focused analysis [21]. More network capacity is not enough to address these concerns; bigger systems mean more points of failure, software versions, and interfaces to deal with. In addition to performance in cellular networks, other reviews of the IoT ecosystem point to security and privacy as issues in connected-device systems [40], [41].

Network slicing and Edge computing present opportunities and responsibilities. Isolation and authorization must be implemented and monitored appropriately in order to achieve the benefits of slicing in separating traffic or delivering differentiated services. While edge processing can help minimize data transfer, it can also help spread out sensitive data and security responsibilities to more locations. For 5G IoT architecture and trust, device compatibility, device authentication, privacy, and security for the heterogeneous connections are highlighted [6], [8], [40]. These are design requirements and not a guarantee that any one solution proposed to provide security is effective in practice. Another point in favor of 5G-IoT trust management is that device-to-device interactions necessitate trust evaluation, in addition to slicing, to handle various latency, bandwidth, and reliability requirements [6]. Ethical and social issues are also included in the growing security umbrella of IoT [42] and a qualitative discussion on 5G-IoT risks highlights the importance of the accuracy of the data and of its reliable transfer from one device to another in order for the automation to be beneficial [43].

5.2 Energy, coverage, and infrastructure cost

The use of energy is a system-level trade-off. In some cases, 5G could make it easier to communicate or process data at the edge, but battery-powered devices are still limited in their energy budget, and network infrastructure consumes energy. Studies have underlined energy measurement as a key feature in the deployment of real IoT applications [10], [12], [44] and low-power operation as one of the essential requirements for IoT. The reason why NB-IoT and other LPWAN technologies are still relevant is that not all sensors can profit from the high data rates and low latency that are associated with broadband. The relevance of NB-IoT and other LPWAN technologies is due to the fact that not every sensor needs to be connected to the broadband data rate and low latency requirements. “5G is more energy efficient” should therefore not be considered a device-level statement without further context of the comparison, traffic profile, radio state, and system boundary. The introduction of a proposed 5G-core enhancement for battery-less ambient IoT devices serves as a prime example of the fact that such ultra-low-energy devices may need to have additional network functions and security procedures, rather than just being supported by the existing network architecture [45].

Other factors influencing adoption are coverage and cost. Researchers say that the key infrastructure needs to achieve performance benefits include infrastructure investment, new sites or access units, spectrum, and network upgrades [21], [46]. Other works centered on real-time processing of IoT devices indicate that network variability, device constraints, congestion, and resource allocation are factors that can impede the ability to consistently deliver real-time services [47]. The usefulness of it will probably differ between environments with a high density of industrial or urban development and environments with low connectivity and sparseness. Other literature on deployment in developing economies also highlights affordability, infrastructure, skills, and digital divide issues [48]. Having a favorable latency or capacity profile is only one part of the equation if you want to show economic viability or equitable access.

Integrate into the operation and share information with other systems.

5.3 Interoperability and operational integration.

The IoT ecosystems are built from the components of devices, gateways, communication technologies, cloud platforms, and application vendors. Interoperability and standards have been identified as ongoing problems in the literature, such as compatibility between sensors, platforms, gateways, and software [3, 21, 29]. When thinking about the industrial field, the need to connect the new technology with existing equipment and systems [25, 30] comes in. Other papers provide a broad overview of the communication options for IoT and explore slicing and light machine-to-machine protocols as integration methods [29, 49]. In addition to the standards identified and the compatibility issues, this means that service continuity relies on factors other than radio performance [3], [21]. If it is not interoperable, a radio network's high performance can be a key element of a standalone solution and not a complete end-to-end service.

The main synthesis is a linkage between benefits and risks. The greater connectivity and flexible network services of richer applications bring higher requirements for security management, energy planning, systems integration, and lifecycle investment. That's why the impact of 5G cannot only be estimated based on the radio access capability but

rather according to the overall IoT service [13], [39], [50]. Other publications focus on the architecture of the industrial IoT and connectivity options for cellular and lack abstracts that provide common outcome measures for evaluation of implementations

VI. COMPARISON OF EVIDENCE DESIGNS

The evidence-design table below compares selected reviews, simulations, and a practical implementation; study details are limited to what the abstracts reported.

Table I. Selected publications and reported evidence design.

Study	Design or evidence type	Setting / system described	Main contribution reported	Cites
Akpakwu et al. (2017)	Review	Massive-to-critical IoT communications	Surveys cellular LPWA options, 5G NR enablers, requirements, and open challenges.	[1]
Chettri and Bera (2019)	Review	5G IoT technologies and applications	Organizes network drivers including NR, MIMO, millimeter wave, heterogeneous networks, LPWAN, and security.	[3]
Kar et al. (2021)	Network simulation	Proposed 5G-IoT architecture	Reports approximately 1 Gbit/s throughput and sub-millisecond latency in the simulated architecture.	[20]
Wang et al. (2018)	Experimental result reported in abstract	5G intelligent IoT and channel/QoS optimization	Reports improved channel utilization and QoS; the abstract does not provide a numerical estimate.	[51]
Meira et al. (2023)	Practical implementation	Industrial shop floor at Bosch Termotecnologia	Describes 5G IoT sensing and an intelligent assistant, tested and validated in a real factory environment.	[30]
Patil et al. (2025)	Predictive resource-allocation simulation	5G mMTC for smart-city, healthcare, and industrial IoT	Reports improved latency and throughput versus traditional allocation; forecasting accuracy was reported for latency and bandwidth.	[24]
Ahmed et al. (2024)	Security survey	5G-enabled IoT architecture	Synthesizes privacy, security, interoperability, and system-design concerns.	[8]
Love and Jamal (2020)	Article on deployment implications	5G integration in IoT projects	Identifies infrastructure, malware/intrusion, device security, and interoperability barriers.	[21]

The evidence designs give answers to various questions. Evaluates map needs and technology options without impact; does not show impact of map deployment. Simulation tests simulate conditions and reveal feasibility or can compare configurations but are not indicative of the results in the field and are based on assumptions. The abstract doesn't offer an element of a controlled counterfactual or quantified effect, although the Bosch shop-floor account is one possible implementation context. So more can be said for the literature on the architectural plausibility of the benefits of actual operation than for the broader claims of actual operational benefits.

VII. RESEARCH GAPS AND IMPLICATIONS

First, there's a need for more field evaluations that have clear baseline statements with a kind of end-to-end approach. The abstracts recovered give simulation metrics and one real-world implementation, but there are few similar real-world results. For a better comparison of results, studies should give the distribution of latencies and tail behavior, packet loss, availability, energy cost per useful task, density, coverage, and results of applications with specified networks and workloads. This would enable useful comparisons to be made between 5G and alternatives (wired or local or low-power wide-area networks for the retrieved evaluations, describe different designs and did not provide a comparable basis) [20], [24], [30], [44].

Second, further research is required that will explore the lifecycle cost and energy of an entire system. Throughput or latency should be included with infrastructure, edge computing, device replacement, spectrum, maintenance, and power consumption. While literature often mentions the cost of infrastructure and energy as constraints for adoption, none of the retrieved abstracts contain similar estimates of the cost-effectiveness across sectors [10] [46] [48]. There are several solutions for cellular connectivity and wide-area connectivity, and this

question of cost and coverage comparisons of access technologies has been explored in reviews of IoT connectivity [13, 49].

Third, security and privacy must be evaluated on an operational basis as well as be proposed. Future works require evaluating interoperability, incident response, edge/cloud data flows, authentication, device identity, device updates, and slice isolation in realistic deployments. In this work, we have found that few of the abstracts give a replicated test in an implemented environment, while security reviews have identified the following as open system-level issues. A few abstracts do not contain a replicated test in an implemented environment, as security reviews have identified the following areas as open system-level issues [6, 8, 21].

Fourthly, studies need to be conducted to pinpoint those regions that require 5G in the first place. There are a variety of priorities of data rate, latency, reliability, mobility, power, and coverage that different applications could and should have, and some of these can be met with existing cellular IoT or local solutions. Comparative analysis should categorize applications by the requirements and compare the details of the scenarios where to make an exception for slicing, URLLC, mMTC, edge processing, NB-IoT, or non-cellular approaches [1, 5, 11]. This "one-for-one" matching would be more useful than the view that there will be one access network that fits the whole IoT ecosystem. The evaluation stack suggested below attempts to distinguish between network-level factors and factors associated with devices, with application and deployment outcome factors as a basis for not believing that a change at the network level alone will yield more general benefit.

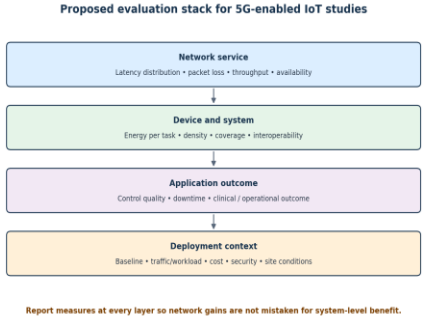


Figure 3: Proposed Multi-Layer Evaluation Framework for 5G-Enabled IoT Systems.

VIII. CONCLUSION

The capabilities of 5G, higher scalability of cellular access, network programmability, and edge computing create an opportunity to design a new space for IoT.

These enablers span dense sensing, mobile data-rich applications, and time-critical applications in industrial and public settings. The literature is inspiring, with some simulation results and only one industrial application, but the evidence they cite does not sufficiently support the assumptions of ubiquitous performance for the solutions they advertise or their universal impact across the economy. Other design factors include security, privacy, interoperability, power, coverage, and cost. The overall answer is that 5G, unless the application's requirements align with the opportunities, will not be an enabler for IoT unless the solution is thoughtfully designed and assessed. Further research will require gathering more field performance data reporting technical, operational, economic, and security results.

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