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A Review of the Emerging Research Issues in the Internet of Things Low Power Networks (IoT-LPNets)

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***ABSTRACT**: The emerging Low-Power Networks (LPNets) technologies have been particularly appealing to various Internet-of-Things (IoT) applications, due to some of their key features; long communication range, a simple star network topology and low power consumption. These reduce costs, need of hardware equipments and increase safety. Also, range of parameters configurations; spreading factor, bandwidth, coding rate, carrier frequency, and transmission power among others. It has been observed that still other challenges attached to the technology were still remain bottle-neck. This review exposes such research emerging issues for others to consider. The review considered most recent articles from internationally recognized publishers, reveals support decision tools used, parameters optimized, taxonomy of IoT-LPNets; which serve as a novelty of the current review with a view to assist upcoming researchers to explore, exploi, and build further. It is also intended and expected to assist Telecom Operators, Service Providers, users of the LP-Nets technologies and its readership.*

***KEYWORDS:** Internet of Things (IoT), Low-Power Networks (LP-Nets), Low-Power Wide Area Network (LP-WAN), Long Range (LoRa)*

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I. INTRODUCTION

The Internet of Things (IoT) is the culmination of developments in electronics, networking technology and the Web, all combined with the human desire to enhance quality of life. The IoT spread into many aspects of life, including smart homes, cities, manufacturing, schools and workplaces. The physical everyday items; lights, locks and industrial machinery can now form part of the IoT ecosystem. The IoT has redefined the management of critical and non-critical systems in order to make lives safer, more efficient and more comfortable. Consequently, IoT technology has a very positive effect on lives (Ande, Bamidele, Mohammad & Jibran, 2020).While Lower Power Wide Area Networks (LPWAN) is wireless connectivity tools for Internet of Things (IoT) applications of industrial automation systems (De-Souza, Hoeller, Souza, Montejo-Sanchez, Alves, & De-Noronha, 2020). Also, the IoT refers to devices with specific identities and capabilities to perform remote sensing, tracking and temporarily storage of certain blocks of data. The IoT is a cross-platform where computers get smarter, computation is smarter and communication leads to insightful. The IoT devices are also able to share data with other devices and applications in real time, either directly or indirectly. Any IoT-based device consists of Input/ Output interface for sensors, interface for connecting to the internet, interface for memory/storage and interface for Audio/ Video (Boursianis et al, 2020). These inspirations motivated the researchers and improve the efficiency of the LP-WAN ecosystem at the city-scale; improving the communication capabilities of LP-WANs, leveraging LP-WAN deployments to sense and securing the LP-WAN clients from malicious adversaries (Gadre, 2020).

II. THE MOTIVATION / CONTRIBUTIONS OF THE CURRENT REVIEW

However, we observed that researches and reviews in IoT-LPNets are on record; Gadre, et al (2020), Hoeller et al (2020), Rajab et al (2020), Tresca et al (2020), Boursianis *et al* (2020) among others. Despite these, revealing comprehensive emerging research issues, standard sources of the review, taxonomy, research decision support tools, summary of parameters analyzed etc remain emitted. In order to intimate upcoming researchers to design new method for wider coverage, reduce transmission power, minimal packet collisions, this review reveals various challenging issues in a dense network deploying IoT devices from gateway to end nodes. As such, most recent research challenging issues to power consumption and related cases for the upcoming researchers to address were simply tabulated. The central aim is for researchers to come up with a new design/method to accommodate higher number of number nodes and variable transmission power in order to improve the performance and reduce power consumption rate in the network. Again, to improve the performance by reducing the frequency of collision probability, optimize Spreading Factor (SF) Band Width (BW) and Coding Rate (CR) among others. This review also has the highest expectation that Telecom Operators, Service Providers, Users and its readership will benefit from. The bench mark is Boursianis *et al* (2020) as the remaining sections were segmented in section 2 is the main objectives that motivated the contributions of the Review, 3 consists the outline of methods in the IoT-LPWAN, 4 the application IoT technology in everyday life and 5 the Basic IoT communication protocols & Cloud computing service. Other sections are 6 the Application of Lora, 7 tThe graphical Representation of sources, taxonomy, 8 the future trends, challenges and Recommendations in IoT while section 9 concludes the review.

III. THE DESIGNS OUTLINES IN THE IOT-LPWAN

This section summarizes the recent developments in the Internet of Things (IoT) Low Power Networks (LPNets). So, articles of reputable standard were consulted and researchers' works were highlighted as reference materials to the review:

It was acknowledged that the lack of a systematic review of the design objectives and the decisions made was in the past. The analysis of six (6) prominent design goals was made and identified design decisions in the eight LPWAN technologies to meet each goal; ranging from technical consideration to business model. They presented system architecture and specifications for these LPWAN solutions, and assessed their ability to meet each design objective. So, seventeen use cases across twelve domains that require large low power network infrastructure and prioritize each design goal's importance to those applications as Low, Moderate, or High were outlined (Ben et al, 2020). It was identified that one of the techniques to increase the reliability of LORAWAN is message replication. They proposed a novel hybrid coded message replication scheme that interleaves simple repetition and coded replication method. They show that it enhances the network performance without requiring additional transmit power compared to the competing replication techniques (De-Souza, Arliones, Richard, Samuel, Hirley, & Mario, 2020).The advent of low-power internet-of-things(IoT) technologies, city-scale IoT is expected to bridge everyday objects to the cloud. So, connecting objects at that scale requires a wireless technology that provides long battery life and range of communication. However, LP-WAN clients achieve optimum performance in rural areas and severely underperform in urban cities due to interference, worse multipath, susceptible to security threats. As such, propose to improve the connectivity, sensing capability and security of LP-WAN clients in the urban ecosystem (Gadre, 2020). In multipath-rich urban environments, received signal power varies rapidly with a low-power transmitter's frequency, impacting its transmission time, data rate and battery life (Gadre, Revathy, Anh, Anthony, Bob & Swarun, 2020). It was identified that the roles of Low-Power Wide-Area Networks (LPWAN) in the cellular Internet-of-Things (IoT) infrastructure is to support massive Machine-Type Communications (mMTC) beyond 5th generation (5G) wireless systems. They also presented a performance analysis of current LPWAN systems, specifically LoRaWAN, in terms of coverage and throughput (Hoeller, Sant'Ana, Markkula, Mikhaylov, Souza &Alves, 2020).It has been proposed to address LoRa networks scalability when the number of end nodes connected to one network is larger than the shared number of channels, which causes a collision and packet loss through receiving a wide range of different message sizes from various applications. They described an accurate and efficient way as confirmed through simulation, which calculates the probability of collision rate and packet loss in LPWANs under various circumstances (Rajab, Tibor &Taoufik, 2020). It has been evaluated that Long Range Wide Area Network(LoRaWAN) in realistic and human-centric construction work environments, i.e., error, reliability, and otherpractical benefits (Teizer, Neve, Wandahl, König, Ochner, …Lerche, 2020).They proposed a Narrow Band Internet of Things (NB-IoT), a low power wide area network (LPWAN) technique, which enables high capacity, wide coverage, and low power consumption communications. However, with the increasing demand for services over their, wireless spectrum is becoming scarce and new techniques are required to boost the number of connected devices within a limited spectral resource to meet the service requirements. They provided a compressed signal waveform solution "Fast-Orthogonal Frequency Division Multiplexing (Fast-OFDM)" to double potentially the number of connected devices by compressing occupied bandwidth of each device without compromising data rate and bit error rate performance. The simulations first evaluated for the Fast-OFDM with comparisons to Single Carrier-Frequency Division Multiple Access (SC-FDMA) (Tongyang & Izzat, 2020). In the context of environmental monitoring, many LoRa-compliant solutions are now available. They proposed analysis of rapid prototyping platforms that leverage both the simplicity and effectiveness of the LoRa technology in the context of outdoor communications (Tresca, Francesco & Pietro, 2020).It was proposed to address the existing monitoring system; data transmission, parameter accuracy and transmission distance. As such, proposed a novel transmission tower tilt monitoring system. (Zhang, Yan, Lin, Jian, Wenbin, Mingming & Xitong, 2020).

The development of IoT devices is expected to rise drastically in the next couple of years. It is forecast that there are 50 billion devices connected to the Internet in 2020 and by 2022 the number is expected to reach 1 trillion. All these devices need to be powered using rechargeable or non-rechargeable batteries. Power becomes the major challenge for these IoT devices especially when they operate in the long-range in the order of 10km to 15km. Many IoT applications require long-range devices. These IoT applications include environmental monitoring in large rural areas, agriculture and smart-cities. The Long-range wide area network (LoRaWAN) is currently the most widely used low power solution for long-range applications. Studies of the energy performance of the LoRaWAN reveal a relatively high energy consumption resulting in a maximum operating period of 1 year using 2400mAh battery with a transmission interval of 5 minutes. The LoRaWAN, like most IoT wireless systems, utilizes duty cycling to reduce the power consumption of the node (Frøytlog et al., 2019). The provision of connectivity to some major IoT devices has been a challenge. On one hand, connectivity based on cellular technologies offered too much bandwidth for many IoT applications. On the other hand, the associated power consumption was too high. This caused repetitive recharging for tracking solutions or requiring 'clunky' form factors limiting the development of tracking use cases. As such, new connectivity technologies are required to power the IoT devices. LoRa provides a solution to many of the issues highlighted above. They are currently quite rightly so considered as one of the 'hottest innovation areas in telecoms'. Low energy consumption, deep indoor penetration for a low cost at limited data rates characterizes these types of technology. They have the potential to enable a new playground for innovators, whose use cases are yet to be invented. Hence, LPWA technologies have the potential for exponential growth not only because they may enable use cases in terms of having a positive impact on their business case, but also open new possibilities which are unlocked by its unique characteristics (Weber et al., 2019). So, currently, there are several competing LPWA technologies utilized in IoT devices, each with unique behaviors geared towards achieving communication at low power over a long range (Qin et al., 2019).The Low Power Wide Area Networks (LPWAN) is being deployed in increasing magnitudes as its market size is increasing at Compound Annual Growth Rate (CAGR) of more than 90%. Internet of Things (IoT), which is foreseen to be the future of smart living, heavily relies on LPWAN technologies to ensure extended coverage in both outdoor urban and rural settings. The reliability of LPWAN technology as a result of its long rage, low power, and resilient frequency hopping qualifies it as ideal candidate for dense IoT deployments covering possibly hundreds of square kilometers in complex terrain settings. Their analysis further examined various techniques for LPWAN wireless planning pipeline. They examine network-aware approach using K-means clustering and a network-agnostics approach using Grid method. Conversely, using the computational method for GW placement like Spatial Method (SM), has a potential of creating competitive network performance using just the same number of GWs, thus cutting down the financial costs of the network, optimizing power and increasing its sustainability (Mina et al., 2019).LoRa provides significantly long range communications. It reduces costs and need of hardware equipment and also increases safety and coverage. However, directional antenna can be used to decline the unwanted effects of interference of neighbor networks or nodes from that network (Abbasi et al., 2019). Qin et al., (2019) revealed that LPWA networks are attracting extensive attention due to their ability to offer low-cost and massive connectivity to IoT devices distributed over wide geographical areas. Analysis from their test field-results highlighted some challenges that prevent LPWA technologies from moving from theory to wide-spread practice. Furthermore, because most LPWAN technologies operate in the relatively congested industrial, scientific and medical (ISM) band, they are invariably prone to problems such as spectra congestion, which causes interference, reduced transmission range, limited scalability, and spectra efficiency. Thus, in recent times, some pioneering researchers and developers alike, are tackling these problems base on the integration of cognitive radio (CR) technologies in LPWAN (termed CR-LPWAN). Accordingly, the advantages from using CR-LPWAN systems include: improve spectra utilization, reduced transmit power constraints, longer transmission ranges, low device development and network deployment cost. However, a few limitations are existent, which are mainly CR-based problems, concisely related to CR-LPWAN systems under areas such as rendezvous in ad-hoc CR-LPWAN systems, spectrum sensing, spectrum mobility, adaptive CR technologies, interoperability and security issues (Onumanyi et al., 2019).

The exponential increase in the number of connected users and devices in the Internet of Things (IoT) and the requirements for connectivity (e.g., coverage, battery life and deployment cost) are evolving to ensure effective communication between these devices. The emerging low power wide area network (LP-WAN) technologies have been particularly appealing to various IoT applications, due to some of their key features, such as long communication range covering few kilometers, simple star network topology and low power consumption (Dhaval, 2018).The rapid growth in the number of LP-WAN was as a result of its low-cost of communication, although IOT is gaining more popularity, However, the suitability of LP-WAN is still under investigation, LoRa and Sigfox was evaluated using a simulation model developed by the researchers to evaluate the influence of the number of devices on LoRa and Sigfox performance by measuring packet error rate, collision, and spectrum, under different values of the number of IoT devices (Niemah& Osman, 2018).An enhanced Gaussian process based localization (EGPL) using a low power wide area network was proposed to enhance maximum likelihood estimation (MLE) process by considering the indoor/outdoor propagation hypotheses. The scheme effectively deals with intermittent signals over a large area caused by low communication throughput and interference or packet collisions in LP-WAN (Zhe, You, Ling & Kyle, 2018).A new LP-WAN architecture called sensor network over white spaces (SNOW) was proposed to support asynchronous, reliable, bi-directional, and concurrent communication between numerous sensors and a base station. The technique works by exploiting the TV white spaces (Abusayeed, Mahbubur , Dali, Chenyang, Jie , Ranveer& Chandra, 2018). It is important to detect malfunctions and abnormal events in IoT devices to provide a secure and reliable communication. Therefore, low-latency Fog-based anomaly detection approach for IoT applications in 5G Smart Cities has been presented to identify unusual events or abnormal patterns in IoT scenarios, the scheme focuses on low-power Fog Computing solutions and evaluated within the scope of Antwerp's city of Things test-bed based on a large data set collected using Unsupervised Clustering and Outlier detection algorithms (Jos, Philip, Tim, Bruno &Filip, 2018). The powerful cognitive ability that enables efficient access to smart devices was as a result of rapid growth in AI and IOT technology. They focus on 4G, 5G, LoRA, SigFox and other LP-WAN technologies. The scheme safeguards stable and efficient communications in a heterogeneous IoT by putting forward a cognitive LP-WAN architecture, for efficient and convenient utilization of the AI, variety of LP-WAN technologies to safeguard the network layer were used, AI-enabled LP-WAN hybrid method was used to balance the demand for heterogeneous IoT devices with the communication delay and energy consumption. The smart control of wireless-communication technology and intelligent applications was provided by the AI algorithm. The experimental results show that Cognitive-LP-WAN selects appropriate communication technologies to achieve a better interaction experience, the scheme also meets the demands of communication delay applications. (Min, Yiming, Xin, Xiao, & Iztok, 2018).It was identified that The LoRa communication protocol is more suitable to be used in IoT applications where the maximum number of packets sent per day by the node are restricted (Alexandru& Adrian, 2018). The IoT deployment for city scale air quality (AQ) monitoring with Low-Power Wide Area Networks was proposed to facilitate more granular city coverage without limitations of network access on LoRaWAN, six Air Quality devices with low-cost particulate Matters (PM) sensors were built and deployed in two locations within the city. The devices are equipped with LoRaWAN wireless network transceivers to test city scale Low-Power Wide Area Network coverage. It was identified that some low-cost PM sensors are applicable for monitoring AQ, likewise, it shows that the design can be used via LoRaWAN enabled AQ sensor network deployment within the city. However, the data quality may be defenseless against interference from climate conditions (Steven, Philip, Florentin, Mihaela, Gavin & Matthew, 2018).An automatic key generation for long-range wireless communications in LP-WAN was proposed to investigate the automatic key generation performance in a long-range environment. The scheme uses LoRa as a case study; to extract a high level of randomness, differential quantization is adopted. Experiments conducted both in an indoor and outdoor urban environment show that, secure keys could be reliably generated. Key generation application in LoRaWAN was also discussed and was shown to be feasible by leveraging the uplink confirmed data packet, and downlink ACK packet (Junqing, Alan, &Lajos,2018).It was identified that, Narrowband IoT (NB-IoT) is a LP-WAN technique, a design for saving bandwidth and doubling the number of connected devices was proposed to double the number of connected devices by using bandwidth compressed signal waveforms. The number of connected devices was doubled by compressing the occupied bandwidth of each device without compromising data rate and bit error rate (BER) performance (Xu & Darwazeh, 2018).

The identification of the geographic location of a user or computing devices is normally based on network routing addresses or internal GPS units. Due to the growing of Internet of Things in multiple applications and the need for geo-location and tracking capabilities, aLoRaWAN tracking system was designed and implemented. The new system is able to exploit the transmitted packages and accurately identify the position of the devices using low power technology. The system reduces the average power consumption to 12.9 mA compared to 400-600 mA using GPS + GSM for a transmission time of 2.8 seconds. Multi-lateration algorithm was applied on the gateways timestamps from received packages to calculate the geo-location. The system was designed using an end-node, four gateways, a server and a java application (Fargas & Petersen, 2017). An experimental study was conducted to relate the performance and the mobility of LPWAN in order to understand whether it is suitable for mobile IoT. The study discovered that LPWAN can easily be affected by mobility based on the distance to the gateway and the environment where the end node is placed. The result shows that, there is need to develop a mobility-aware LPWAN protocol in addressing the mobility issue in the mobile IoT. (Patel & Won, 2017). The impact of three basic parameters (code rate, spreading factor and bandwidth) that characterized LoRa are analyzed. The result shows that, LoRa provides five code rates for forward error correction which permit the recovery of bits information due corruption by interference. Longer range is provided by higher spreading factor (Noreen, Bounceur & Clavier, 2017). LoRaWANis seen as a promising technology to achieve the low-power and long-range requirements. LoRaWAN provides three different device classes (A, B and C), which provide a trade- off between performance (i.e., throughput and latency) and energy consumption. In order to accurately measure the power consumption, we used a well-known

LoRa board that can operate both in class A and class C mode. A high-end resistive current sensing circuit was used to measure the power consumption of the chip in different operating modes (TX, RX, idle and sleep). The results shows that, for a class A device, it is possible to obtain the 10-year operational goal if care is taken to use the proper payload size, transmission interval and to use a spreading factor that is as low as possible. (Cheong,Bergs, Hawinkel, &Famaey, 2017).

3.1 The Summary the Current Research Issues in IoT-LPNets:

S/n	Author(s)	Network Parameters	Adopted Method(s)	Decision Tool(s) Employed	Research Issue(s) (Gaps)
1	Ben et al (2020)	Performance, scalability, security and standardization	Analysis of design goals & decision based on system architecture and specifications		Developing a new LPWANs platform for underground water
2	De-Souza et al (2020)	Time diversity, message replication, simple repetition, minimum reliability and network performance	The coded replication technique through optimization analysis	Numerical evaluation of success.	Testing the scheme in a testbed
3	Gadre (2020)	connectivity, sensing, capability, range, battery life, throughput and security	The design of narrow bandwidth and client-based station dichotomy for minimal compute, storage and power Resources		The design of a high data rate urban ecosystem that will synergize with LP-WAN deployments for cross-technology sensing of the environment.
4	Gadre, et al (2020)	battery life, transmitting time, bandwidth, data rate and performance	They used Chime on a campus-scale test bed. A Chime is a system enabling LP-WAN base stations to identify an optimal frequency of operation after the client sends one packet at one frequency.	Chime using LoRa, Semtech SX1276 chips and base-stations on six buildings	An end-to-end system to provide enormous battery savings to low-power clients, while respecting hardware limitations remains an important issue
5	Hoeller et al (2020)	massive Machine-Type Communications (mMTC), coverage & throughput	Analytic methods and network simulations for a more comprehensive vision. Later identified possible performance bottlenecks, speculate on the characteristics of coming IoT applications	Riverbed Modeler	A post-5G converge LPWAN connectivity for feature operations in both licensed and unlicensed bands with time- and frequency-division to grant-based channel access.
6	Rajab et al (2020)	Scalability, low power consumptions, collision rate and packet loss	Time scheduling and distance spreading factor algorithms	Matlab	An optimal algorithm using machine learning based on our scheduling algorithm to find the optimal gateway placement and optimize power consumption
7	Teizer, et al (2020)	Performance, long range (LoRa), error and reliability	The construction equipment tracking and monitoring applications exploring the TRACI architecture for its potential of tracking and monitoring construction labor. They focused on setting on testing TRACI in a safe construction-like laboratory setting (an outdoor construction, education and training environment).	TRACI GNSS data logger.	The evaluation of the performance of n daily work practices (larger/longer operation scales) as well as its impact on humans, ethical and user privacy issues.
8	Tongyang&Izzat (2020)	The Narrowband Internet of Things (NB-IoT)'s data rate, bit error rate performance,	The compressed signal waveform solution, termed fast-orthogonal frequency division multiplexing (Fast-OFDM),	Additive white Gaussian noise channel	The ability to lead further new research directions in extending coverage; enhancing capacity

			to double potentially the number of connected devices by compressing occupied bandwidth of each device without compromising data rate and bit error rate performance		and improving data rates for 5G NR NB-IoT networks
9	Tresca et al (2020)	Spreading Factor (SF), Bandwidth (BW), and Coding Rate (CR)	A case-study analysis of rapid prototyping platforms that leverage both the simplicity and effectiveness of the LoRa technology in the context of outdoor communications.	The communication range in urban environments via Gateway	Using a higher number of nodes and variable transmission power in challenging operational scenarios, i.e., industrial plants.
10	Zhang et al (2020)	Data transmission, parameter accuracy and transmission distance	A novel transmission tower tilt ministering system for LPWAN; LoRa (Long Range), NB-IoT (Narrow Band-Internet of Things). The tilt parameters of tower were uploaded, NB-IoT module upload the tilt information to the cloud platform, then administrators can arrange timely targeted maintenance for transmission towers with faults according to the analysis results.	MPU6050 tilt sensor, power and a LoRa module.	The addition of more nodes to monitor a wider area, and improve the present monitoring system.
11	Abbasi et al (2019)	Spreading factor, bandwidth, coding rate, carrier frequency, and transmission power	Simulations were used to demonstrate that, in the majority of cases, LoRa is sensitive to the number of nodes. Secondly, in a typical experiment, by increasing the number of nodes, energy consumption of the network increases subsequently.	Smart grid use cases based on the LoRa Technology.	The use of directional antenna to decline the unwanted effects of interference of neighbor networks or nodes from that networks.
12	Frøytlog et al (2019)	on-demand wake-up radio, and custom narrowband low noise amplifier,	A prototype was used.	LNA (Low Noise Amplifier)	The low-power solution for the long-range IoT devices by employing an on-demand wakeup radio solution.
13	Mina et al (2019)	IoT Gateways (GWs), wireless, optimization, LPWAN, clustering	Experimentation.	Machine learning tool (K-means clustering) for determination of optimal GW location.	Uncover design principles for how to efficiently deploy GWs to maximize the efficiency of future networks.
14	Onumanyi et al (2019)	Cognitive Radio, Industrial, Internet of Things, LPWAN	Survey		State-of-the-art approaches, along with a network architecture and PHY layer model suitable for the integration of CR in LPWAN (termed CR-LPWAN).
15	Guet al (2019)	Cost, bandwidth, coverage	Survey		Evaluate the performance of LPWAN in different metrics including coverage, bandwidth, and cost.
16	Qin et al (2019)	Large scale deployment of Narrow-Band IOT, and LoRa	Review		The challenges that prevent LPWAN technologies from moving from theory to wide-spread practice.
17	Weberet al. (2019)	Quality of Service (QoS), and Service	Case study and Experiment.		The possible challenges with QoS

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		Level Agreements (SLAs).			and SLA involved in LPWAN.
18	Niemah& Osman (2018)	Performance, packet error rate, collision, and spectrum,	They analyze, evaluate and characterize LPWANs in both indoor and outdoor environments with changing degrees of mobility	Simulation model developed to evaluate the influence of the number of devices on LoRa and Sigfox	Developing better evaluation technique that will reduce packet error rate and collision in high system load
19	Zheet al (2018)	Accuracy, mean position errors	Parametric hypotheses model by considering the indoor/outdoor propagation hypotheses	Field tests of over a 37,500 square meter area have been conducted	The ability to lead further new research directions in Improving position accuracy above 59.9% during intermittent signal arrival
20	Abusayeed et al (2018)	Energy, latency, and scalability of the sensor network	Exploiting the TV white spaces. It has a new physical layer design which uses a D-OFDM as a novel adoption in LP-WAN for multiple accesses in both directions	Experiments through deployments in three radio environments and simulation were used.	Developing a technique that will reduce the complexity of SNOW
21	Jos et al (2018)	Latency, Delay	Evaluation of low-power Fog Computing solutions based on a large data set collected using Unsupervised Clustering and Outlier detection algorithms	Evaluation of suitable set of LP-WAN technologies	Developing a technique with high data rates
22	Min, et al (2018)	Frequency spectrum, bandwidth & data rate	Considering AIWAC emotion interaction system, build the Cognitive-LPWAN and test the proposed AI-enabled LPWA hybrid method	Evaluation of AI enabled LPWA hybrid method	Developing a robust technique for better real time management and energy consumption
23	Alexandru& Adrian (2018)	large number of nodes & standardization	Analysis of the LoRaWAN communication protocol.	Analytical model to analyze the main features and mechanisms	Implement high-density wireless sensor networks
24	Steven, et al(2018).	Maintenance and control of AQ	six Air Quality devices equipped with LoRaWAN transceivers with low-cost particulate Matters (PM) sensors were built and deployed in two locations within the city to test city scale	Experimentation using LoRaWAN as a means to control the AQ IoT Devices	To exploit more environmental characteristics for better sensor operation
25	Junqing, et al(2018)	A high level of randomness	To extract a high level of randomness, differential quantization is adopted	Experiments conducted both in an indoor and outdoor urban environment	
26	Xu&Darwazeh (2018)	Bandwidth, data rates	Bandwidth compressed signal waveforms technique to double the number of users	Simulation Results to evaluate the performance of both systems in AWGN channels	Analyze the extended coverage, and improved data rate of NB-IoT in 5th generation networks
27	Fargas& Petersen (2017)	GPS-free Geolocation, End-node, Gateways and The Things Network TTN	Applying a multilateration algorithm on the gateways timestamps from received packages. The	An end-node, four gateways, a server and a java application to store the obtained data in a MySQL database.	Design and implementation of a LoRaWAN tracking system which is capable of exploiting transmitted packages to calculate the current position without the use of GPS or GSM.

28	Dongare& Rowe (2017)	OpenChirp, session layer, Bluetooth LowEnergy (BLE) and end-node energy consumption	A service model on top of LoRaWAN that acts as a session layer to provide basic encoding and syntax to raw data streams.	A software architecture to register devices, describe transducer properties, transfer data and retrieve historical values	Simplifying the design and deployment of IoT devices across wide areas
29	Thielemans et al (2017)	Contiki OS, standardized IPv6 and LoRa	expand state-of-the-art routing protocols for WSNs (e.g. RPL)	Contiki OS to enable standardized IPv6 LoRa communications.	Implementation of a LoRa based sensor platform that uses the Contiki OS
30	Patel & Won (2017)	suitability of LPWAN forMobile IoT applications	Gateway installed in the middle of the hallway and An end node installed on top of a vehicle	Symphony Link built on LoRaWAN	Experimental study to evaluate, analyzes, and characterizes LPWAN in mobile environments.
31	Noreen et al (2017)	Code Rate (CR), Spreading Factor (SF) and Bandwidth (BW)	In depth analysis of the impact of these three parameters on the data rate and time on air.		Analyzed the performance of LoRa, code rate, spreading factor and bandwidth.
32	Qin & McCann (2017)	Low-complexity matching channel assignment algorithm (MCAA)	An optimal power allocation algorithm to maximize the achieved minimal transmission rate in LPWA networks. Moreover,	Channel assignment algorithm (MCAA)	Investigate the resource efficiency of uplink transmission for low-power wide-area (LPWA) networks.
33	Reynders et al (2017)	Spread spectrum, power and spreading factor	Optimizing the power and spreading factor for each node and allocating distant users to different channels.	Spread spectrum technology	Optimize the packet error rate fairness inside a LoRaWAN cell.
34	Vejlgaard et al (2017)	Sigfox, Telenor cellular site grid both	Compares the coverage of the two IoT network solutions using the existing Telenor cellular site	Real operator site locations, covering 150 km2 of urban areas in Northern Denmark.	Analyze and the coverage and capacity of Sigfox and LoRaWANin a deployment scenario
35	Cheong et al (2017)	Ohmic Law, MAC protocol and spreading factors	A high-end current sensing circuit to gather the voltage levels and temporal variation with increasing payload sizes and spreading factors	LoRa board that can operate both in class A and class C mode. A high-end resistive current sensing circuit	Investigate the power requirements of a LoRaWAN class A and class C device
36	Raza et al (2017)	Machine-to-Machine (M2M) applications, IEEE, IETF, 3GPP and ETSI	Surveyed several emerging LPWA technologies and the standardization activities	Emerging LPWA technologies and the standardization activities	Identifies potential directions to address LPWA technologies limitations and challenges

IV. THE SUMMARY OF SOURCES, NETWORK PARAMETERS, RESEARCH TOOLS & THE IOT'S TAXONOMY:

Fig. 1: shows that part of the publishers consulted, IEEE having the lion share of 44.1%, followed**,** by proceedings of the international conferences with 29.4%, other journals 20.5% while Springer and Elsevier have 3% each. This proved that the sources consulted are of reputable standard worthy for conducting research:

Fig. 1: *Sources of the Review*

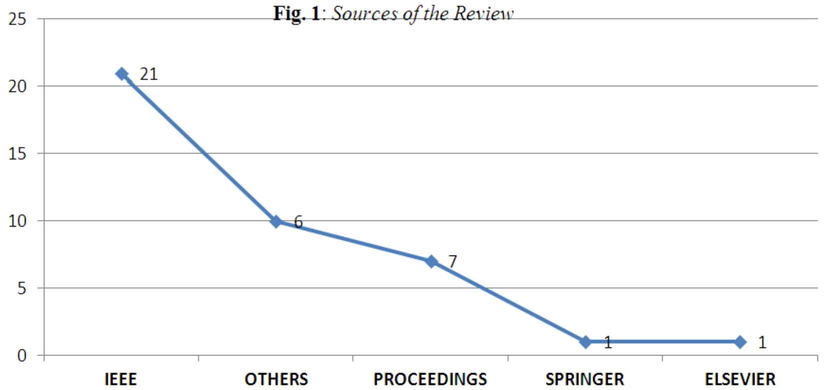
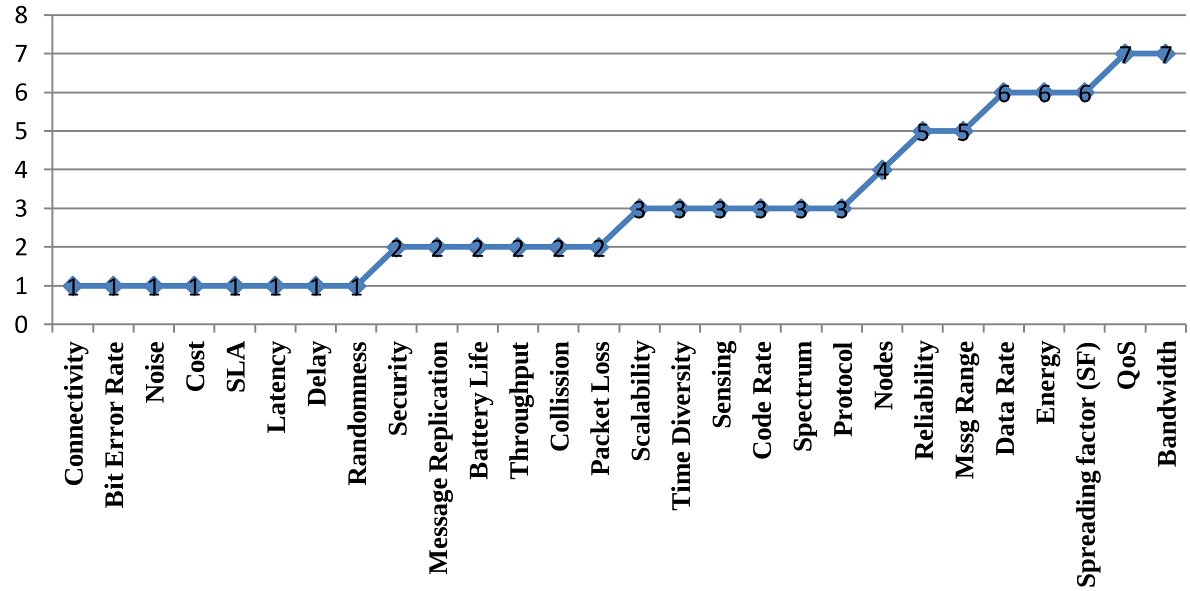


Fig.2 below summarizes the occurrences of the parameters optimized; Bandwidth, Quality of Service with 7 each while spreading factor, energy and data rate with a frequency 6 each. It is observed that message range and network reliability appeared in 5 places and nodes issue has been studied in only 1 instance. Furthermore,

protocol, spectrum, code rate, network sensing, time diversity and scalability parameters each occurred 3 times. In the same vein, packet loss, collision, throughput, battery life, message replication and security were found in 2 places each. The remaining parameters include randomness, delay, latency, SLA, cost, noise, bit error rate and connectivity each with a frequency of 1.

Fig. 2: *Summary of Network Parameters*



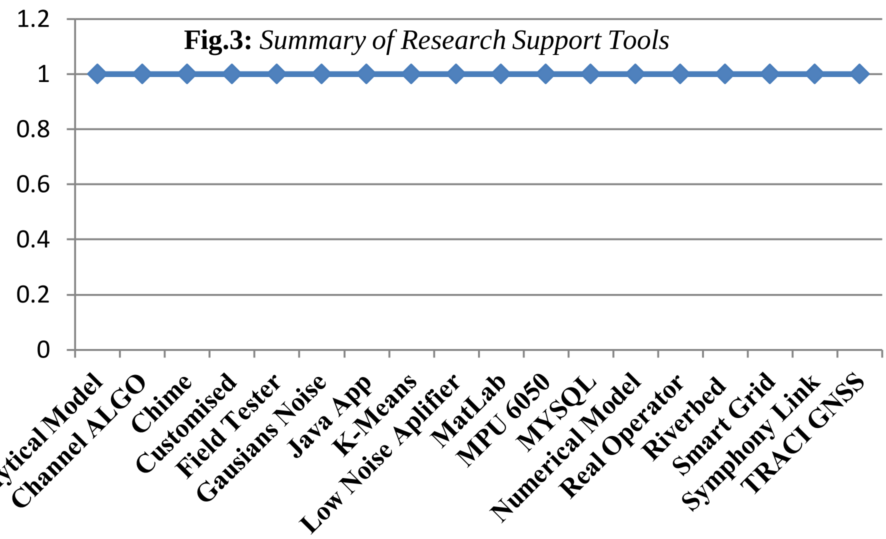
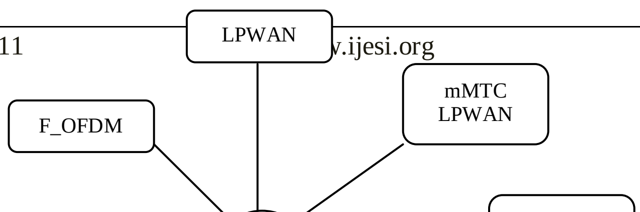


Fig.3: *Summary of Research Support Tools*

Fig. 4 is an extract from the literature of the current review indicates the existence of various technologies used in the Internet-of-Things (IoT) as summarized below. These technologies include Low Power Wide Area Network (LPWAN), massive Machine Type Communication (mMTC), Cognitive Radio (CR), Low Raage (LoRa), LoRaWAN, Narrow Band NB-IoT, SigFox, fast-Othorgonal Frequency Division Multiplexing (F-OFDM) and single Carrier Frequency Division Multiple Access (SC-FDMA:

Fig. 4: Taxonomy of the Technologies in the IoT



V. THE INTERNET-OF-THINGS: FUTURE TRENDS, CHALLENGES AND RECOMMENDATIONS

It has been deduced from the literature of the current review that the IT technologies always emerge and transformed the way we take decision, schedule and help in reshaping brains for innovations. The IoT provides quality, quantity of service and remain user friendliness. This is because, it is easy to install and improve performance in our everyday life. However, still difficult to design and implement by many upcoming researchers. As such, it remains as a major impediment to upcoming research to further improve it for better life by enhancing profit margins and low power consumption.

VI. CONCLUSION

The development of the Internet-of-things (IoT) devices is always increasing rapidly, assumed that about 50 billion devices connected to the Internet in 2020 and expectedly to reach 1 trillion by year 2022 (Frøytlog et al., 2019). This paper admired to review various technologies used in the IoT, the design methods, simulation tools used and parameters that are most frequently optimized. The paper is motivated for the fact that reviews were on records but certain issues remained un-tackled. In this write-up, current research challenges were unrevealed in relation to benefits of the IoT-LpNets for upcoming researchers.

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