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Reliability Evaluation Metrics for Internet of Things, Car Tracking System: A Review

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Abstract—As technology continues to advance, the need to create benchmark or standards for systems becomes a necessity so as to ensure that these new advanced systems functions at its maximum capacity over a long period of time without any failure, fault or errors occurring. The internet of things technology promises a broad range of exciting products and services, with car tracking technology as part of the broad range of technological concept under the internet of things paradigm. The car tracking technology involves deploying some basic internet of things components into the tracking of important transportation component; the basic principle behind any technological concept involves delivery of high quality product that conforms to specifications. In this paper, the concept and technological description about the internet of things is discussed with emphasis on the principal functional component, this is to enable a broaden conceptualization about car tracking technology because it needs to function correctly, at all time. The concept of reliability engineering is also discussed in respect to an important quality factor, which entails that systems must function correctly without fault, failure or errors, it provides benchmark, principles, or standards in which the internet of things system must possess for an increased quality assurance.

Index Terms—Internet of things, reliability engineering, car tracking system, standards, quality.

I. Introduction

Internet of things (IoT) is widely regarded as a technological concept in which objects in our surroundings are given identities. It not only ensures the connectivity of mobile device and humans to the internet but also inanimate objects. It gives objects/things the ability to actively communicate with one another via the internet [1]. Studies over the years suggest that the internet of things technology would evolve beyond the estimated 50 billion units come the year 2020 [2]. The internet of things provides ability for connectivity to anyone at any given place or time. As these technology continues to grow, the evolution in the use of the internet has seen integration of different components into its paradigm [3]. The idea is to allow autonomous and secured connectivity and exchange of information between the abstract world and human activities. It links the real life to the machine and physical world. The number of connected device/objects to the internet is increasing daily e.g., office and home automation, vehicle, machine and asset tracking system. It allows for everyday device, objects/things to be embedded with smart sensors and actuators which can sense, take intelligent decisions on behalf of the user, and perform computation, and also ensures transmission of valuable data from embedded objects through the internet [3]. [4] suggest that the service provided through combination of the key components in the internet of things technology can give birth to valuables services to humans.

[5] The IoT technology consists of different objects, sensor devices, information and communication infrastructure and also a data processing unit. These infrastructures have the ability to operate on the cloud due to huge amount of data processed from smart objects [6]. One of the most commonly used medium for giving objects or things unique identification is the radio frequency identification (RFID) tags, sensors, as well as bar codes. These smart objects, e.g. sensors, RFID tags, creates a medium for communicating objects/things specific information and status over the internet to the user. The combination of these smart device and objects creates services with high processing and quick decision making system [1], [7].

Over the years, the internet of things technology used in intelligent transportation has seen an increase and is widely used in car tracking, monitoring of traffic, asset tracking etc. At the same time, the requirement to ensure the reliability of this technology in respect to its functionality has also increased. [8] “Today it is almost a mandate for companies to collect software metrics as an indication of a maturing software development process”. The technological concept of internet of things car tracking system composes of different features, which includes complex architecture, complex working environment, and fixed network topologies with wide distributed network infrastructures etc., which suggest that with time the problem of reliability, needs to be properly addressed. [9] proposes that a comprehensive evaluation process should be ensured to determine the reliability of the basic components that constitute the IoT systems. Studies from previous and current literatures suggest that there is a need to develop mechanisms that ensures that an internet of things system functions maximally without any interruption or failure. [9], [10] suggest that considering the importance and working principles of most IoT systems, it is pertinently important that a comprehensive evaluation process is developed and used in evaluating its functionality.

Based on study of previous literatures, section 1 introduces the study and the rest of the paper is organized as follows: section 2 gives brief description of previous related works, section 3 describes the prospect of car tracking systems, section 4 gives the working denotation and working principles of IoT, section 5 discusses internet of things essential deployment technologies, section 6 gives an overview on reliability engineering, section 7 shows the importance of reliability evaluation of internet of things, section 8 discusses reliability evaluation model for internet of things and section 9 summarizes and concludes the paper.

II. Related Works

The rise in the use of IoT has enabled users to track the location and activities of vehicle, traffic information, and dispatching of vehicular services, actively. According to [11], there is need to address the quality assurance of service delivery of IoT in the communication process of intelligent transportation system. As a result of the ubiquitous nature of vehicle tracking systems, some fundamental issues as regards to effectiveness and efficiency has to be addressed for better service delivery of this technology. According to [8], [12], [13] the problems associated with dependability of computing systems needs to be properly addressed in respect to quality assurance. Dependability according to ISO/IEC 60300 refers to reliability of any given system [14]. End-to-End quality assurance guarantees that every component that constitute a computing system works efficiently and effectively within the period it is developed to function. A benchmark for quality of service provides assurance that every system functions appropriately. Because of the utmost importance the IoT technology confers on the users, it is necessary for proper evaluation model or framework, which serves as a guideline towards implementation of any given IoT technology. [11], [15], [16] ascertains the need for proper improvement of service delivery of IoT systems through quality assurance mechanisms, and these mechanisms has to be developed and implemented to reduce failures and faults encountered during operation of IoT systems. Due to the paucity state of internet of things car tracking system, [17] proposed that attributes such as availability, reliability and safety has to be imposed on various sub-set of every IoT technology. Reliability and safety are extremely critical attributes that must be imposed so as to provide benchmark for development and implementation of car tracking technology in our environment. The complex nature of these systems makes it sometimes unpredictable and unreliable. It is paramount for the software which constitute the car tracking technology and the various network infrastructure to be highly dependable [17] so as to ensure that every command input/output and packets transmitted via the network are delivered on a timely basis without any interruptions, delay or failures. Considering the importance of this technology, any failure resulting from operations in critical scenario can be detrimental. According to [7] the limitations of mobile technology needs to be acknowledged when developing applications because hindrance in any operational component can make the system function less.

Due to the paucity state of current infrastructure that comprises the internet of things paradigm, the need to develop systems that can stand the test of time is necessary to ensure proper service delivery to the users. The proposed evaluation technique is geared towards providing a benchmark for check listing the basic fundamental functional requirements that IoT systems provide. [10] suggest that the quality assurance of IoT is necessary hence a study of a comprehensive evaluation criteria was proposed for coal mining IoT systems. Coal mine IoT according to the said author, describes the monitoring of equipment's involved in mining process and how they can be made to function maximally. This is to ensure real time monitoring of data needed to provide safety in production, efficiency and effectiveness.

III. GPS Car Tracking System

As a result of technological advancement and continuous popularity of the internet of things paradigm, technologies such as Wireless Sensor Network (WSN), coupled with Radio Frequency Identification (RFID) and the Global Positioning System (GPS) have led to a developed and realistic approach towards real-time tracking of mobile assets e.g., Cars, office equipment [18]. This IoT technology as shown in Fig. 1 has the capability to dynamically give location and status of any given asset i.e. cars, it enables for real time monitoring and control of valuable assets within our environment through the internet. According to [15], [19], IoT technology is an innovative prospect and considered very important hence it is essential that we keep track of valuable assets that are constantly on the move through IoT. GPS utilization in an unstable environment remains an issue considering the importance it has on the users.

The internet of things opens opportunity for an open network in which objects/things has self-organized or intelligent entities that interoperate with other entities and acts independently depending to its scenario [21]. The GPS system applied in car tracking enables easy navigation and monitoring of any car [19], GPS module is an important part of the IoT technological paradigm. In this particular system, the car tracked receives the data through a network from the sensor or RFID tags. The GPS sends data in bytes that contains the location of any object, e.g., car. The location composes of the time, longitude, latitude, and altitude. All of these data is necessitated in tracking and controlling a car in real-time.

Table 1. Previous related works

Author(s) (Year)	Research Area Covered	Research Outcome
Michael R. Lyu (2007)	Software reliability engineering	Effective software reliability engineering techniques to improve product and process reliability
Nkosi, Mzomuhle & Mekuria, Fisseha (2011)	Improving the capacity, reliability life of mobile devices with Cloud Computing	Modelling of mobile cloud computing process in a 3GPP IMS software development and emulator environment and exhibition of security & multimedia operations through cloud computing.
F.Schneidewind, Norman (2012)	Reliability and Maintainability in Software and hardware.	Proposed essential principles and practice for hardware and software reliability with recommended software reliability practice.
Patrick, O'Connor Kleyner, Andre (2012)	Practical reliability engineering	Mathematics for reliability, physics of failure with geographical and software methods of failure and data analysis, reliability prediction and modelling, design for reliability as well as safety and economics of reliability management.
Liu, Zhigang, Zhang, Anqi & Li, Shaojun (2013)	Reliable vehicle tracking through internet of things.	Design and implementation of vehicle anti-theft monitoring system based on GPS technology and GSM technology with android software application controller
Nourhene Maalel, Enrico Natalizio, Abdelmadjid Bouabdallah, Pierre Roux, & Mounir Kellil. (2013)	Reliability for emergency applications in Internet of Things.	Proposed a reliable protocol for data transmission for internet of things. The design protocol runs in an internet of things environment characterized by SIGCOMM computer communication.
Yong-Fei, Li Li-Qin, Tian (2014)	Comprehensive Evaluation Method of Reliability of Internet of Things	Proposed a comprehensive reliability criterion for internet of things based on its architecture as well as a comprehensive reliability evaluation algorithm.
Kunkun, Pan & Xiangong, Li (2014)	Reliability Evaluation of Coal Mine Internet of Things	Applied analytical hierarchical process and mean error methods in order to determine the weight of proposed index in evaluating of internet of things systems in coal mine.
Tom Jenkins, & Ian Bogost (2015)	Designing for the Internet of Things	Provided appropriate latest methodologies, tools and techniques for designing of internet of things.
Chia-Chun Chuang, Wen-Lin Cheng, & Kai-Sheng Hsu (2015)	Quality Assurance for intelligent Transportation.	Managed mobile VPN, fixedline VPN, car device dispatching service platform with a comprehensive service quality assurance monitor. Fault analyzer for quick damage control in intelligent transportation.

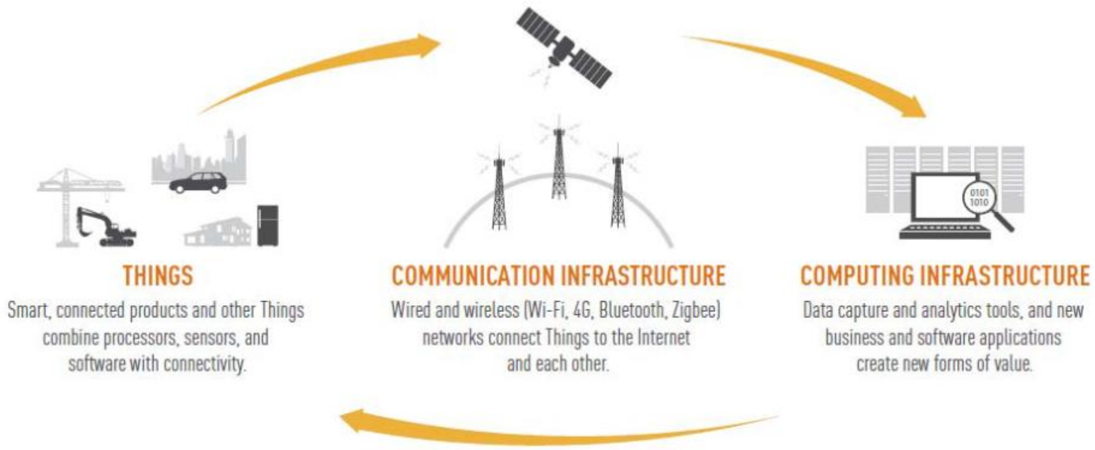

Fig.1. Working principle of tracking with IoT [20].

IV. Working Denotations and Principles

The basic fundamental concept of the IoT revolves around object identification, tracking, locating and also a proper network management platform through which data is dispersed to sensing objects i.e. smart device, Bluetooth device, GPS, etc. This process links any object to a networked infrastructure [5]. According to [22], the IoT comprises of some basic fundamental working principles with telecommunication characteristics towards data sharing through intelligent process. It comprises of the reader, the receiver, the miniature antenna and information-processing unit.

[6] suggest that the internet of things concept revolve

around two basic interactions:

a) *"Internet*" is the core principle.
b) *Objects/things.* This can be characterized as an extension of humans, objects for exchanging information.

For an active participation in data exchanging process, the ioT technology makes use of an electronic tag, the reader, transceiver antenna with data processing unit [23], [24].

- *Electronic tags:*

Often called transponders because of its ability to receive radio signals and automatically transmit the signal to other components. They are microelectronic chips attached to any object to be recognized.

- *Reader:*

This technological component has the ability to scan electronic tags and acquire useful information about the objects status. It comprises of high frequency module (receiver and transmitter), control unit and data-transmission interface which connects and interacts with sensing device e.g. smartphones and PC.

- *Transceiver antenna:*

It is a technological component which comprises of both the receiver, transmitter and serves as a medium through which different components communicate in the internet of things paradigm. It transmits RF between electronic tags and the reader.

- *Information processing system:*

Compose of the basic information processing unit or systems e.g. PC, smartphones, PDA, etc. they receive data about the status of objects/things then process the needed information based on user's specification.

V. Internet of Things Essential Deployment Technologies for Tracking

According to [20], [25], [26], the technological components of the internet of things car tracking system comprises of the following:

1. RFID/Sensors
2. GPS
3. WSN
4. Cloud computing
5. Application software

A. Radio Frequency Identification (RFID)

According to [3] this technology is inform of tags, sensors, barcodes and are easily sensed by smart device, it allows easy communication and interaction between objects/things thereby providing data about its location and status. Represented in Fig 2, is a schematic representation of the RFID tags interact with the user.

According to [22], the recent popular technological trend called the internet of things came to be through a supply chain in which tags were used. It is a technological component which transmits Radio frequency (RF) waves to tags which is incorporated into an object/thing for the main purpose of identification. It comprises of the reader, a tag and computer system. [25] described the RFID as an important internet of things pivotal enabler which has the capability to give any object/thing a unique identification for recognition and communication.

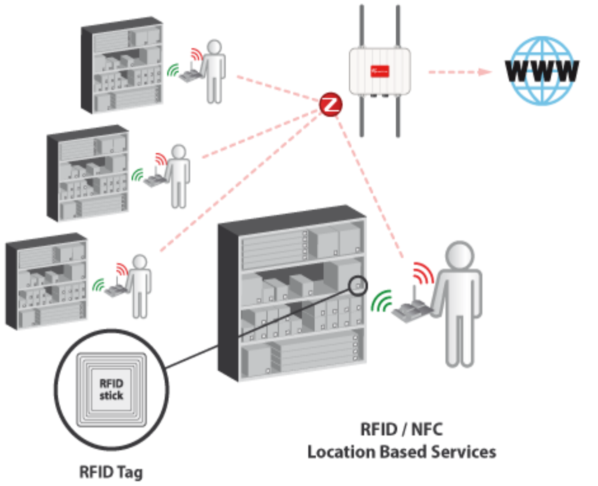

Fig.2. Schematic representation of RFID [27]

B. Wireless Sensor Network (WSN)

The wireless sensor network (WSN) is characterized as an important component in the IoT paradigm because of its ability to provide effective communication platforms for heterogeneous intelligent component [28].

Fig. 3 describes a network of different intelligent objects connected and exchanging data simultaneously over a wide network segment.

This technological component of the IoT ensures visibility by utilizing a networked sensor of large number of intelligent objects, tags, sensors, and RFID. It provides the ability to collect, analyze, process and transmit information through a network between smart objects [29].

C. Global Positioning System (GPS)

With the current technological trend of networked interconnected objects/things through IoT, the ability to track objects has been made possible. According to [30], localization is one of the universal application in the wireless communication technology with the GPS as the main enabler. Mobile device/computers are now enabled with the ability for positioning service with details about anything. The informational status of RFID or smart objects makes it possible for the GPS to locate and communicate with them anywhere.

D. Cloud Computing

Often characterized as a model which enables convenient, ubiquitous, on-demand network access to a pool of configurable computing resources [1]. It serves as the back-end for large data streams for connected things [31]. In the IoT technological paradigm, the cloud computing provides avenue in which uniquely identified objects can store vital information about its status for retrieval by the user when needed. According to [32], applications like transport monitoring with huge connections like WSN applications computes large data stream hence benefits from the computational technology of the cloud.

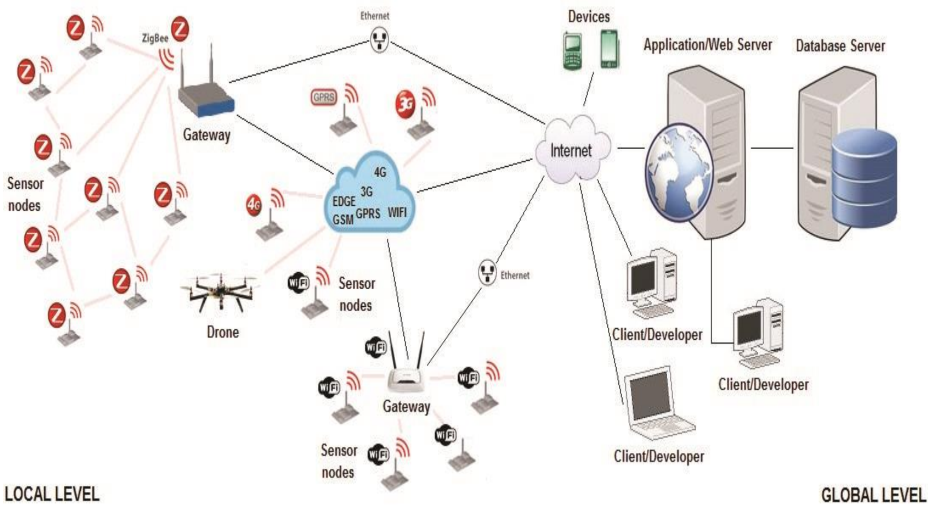

Fig.3. General architectural framework of WSN [26]

E. Application Software

According to [33], application interface serves as a control medium for monitoring and analyzing transitions. The graphical user interface in smart device, computers and phones enables the user to virtually monitor transition of things/objects [20]. It is further noted to be responsible for calculating statistical data for any monitored device or thing.

VI. Reliability Engineering

Reliability engineering refers to the engineering techniques, process, models, etc. use for developing and maintaining systems quality [14]. Technologically, reliability assurance is highly recommended to ensure total quality of a product and its services. According to [8] the concept of reliability cannot be over emphasized due to the dynamic nature of our environment. Most computing and technological components demand high quality operational functionality as well as constant improvement. As technology continues to grow dramatically, it is necessary that quality assurance of product of a system is maintained and improved effectively and efficiently. According to [10], [17], reliability is a technical effort made to ensure a system developed or designed is free from any fault that can result to failure during operation. It entails that the system is highly dependable and functions maximally at any given time or condition over the period it is created or developed to serve [8], [12], [34].

In ISO/IEC 60300, reliability is described the ability of a system to be highly dependable [14], it entails that a computing system must function without failure/faults. In [20], [35], [36] reliability engineering is defined in respect to probability of a system to fail, it is often characterized as the basic fundamental engineering technique that provides significance, and concept for enabling a reliable system, free from failures and highly maintainable system. [37] States that reliability engineering provides a benchmark and guideline towards enabling quality assurance in a computing system. Reliability process therefore mitigates failures/faults that might arise from inconsistences in software systems.

VII. Importance of Reliability Evaluation of Internet of Things

In [3], [38]–[40] Serious emphasis was led on developing reliable system that will serve it specific purpose, reliability engineering process provides techniques to minimizes failure, improve productivity, improve maintenance, and also shorten the time for development and repair of a system.

Currently, the concept of reliability is considered as an important quality factor which mitigates all forms of errors and failures in a functional computing system. It foster productivity, and also maximizes computing systems functionality, this concept of reliability assurance when integrated into the technological paradigm of IoT according to [13] would guarantee trust and trustworthiness during operations.

[7], [16], [36], [42]–[44] suggest that the concept of reliability engineering provides enormous benefits for high operational systems and ensures that the cost of redevelopment and maintenance are eliminated or reduced. It provides high quality benchmark that enables that basic functionality of a computing system must be maintained and constantly improved.

According to [8] the constant result of failure in any given computing systems can result in frustration and also reduce its functionality assurance. Every system, if properly developed with basic reliability principles would improve customer's usability. Customer's usability signifies quality and trust. IoT systems therefore due to its enormous importance and applicability has to be developed in such a manner that it enables easy usage and understanding for the user.

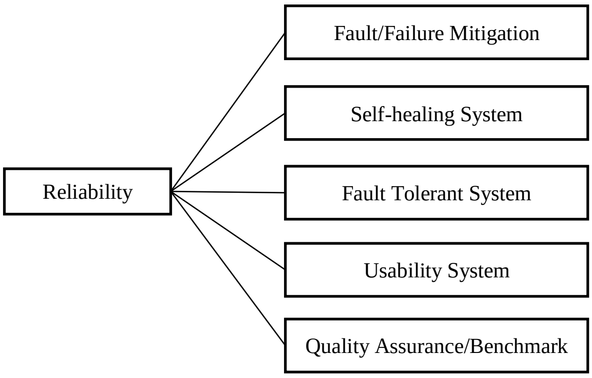

Fig.4. Benefits of reliability [8], [41].

This is considered important because every computing system are developed to serve the user. Quality assurance according to [45] is a necessity and a deterministic factor by which failures can be prevented. It is a basic principle which guides towards conformance to users and different standards.

Self-healing according to [41] is the ability of a smart system to diagnose, discover and swiftly react to disruptions and also maximize resource utilization for the purpose of satisfying the end users. [46] therefore state that self-healing property is necessary for IoT systems because it is necessary that every task assigned to IoT systems are diligently executed without fault/failure and "*objects must me smart enough to recognize different critical situations and take appropriate further measures*".

Fault tolerant is the ability of a computing system to withstand unforeseen circumstance and also prevent discrepancy in service. Fault tolerance is considered as an important mechanism which ensures mitigation of faults or failure in a computing system [8]. Reliability therefore provides much needed benchmark and quality assurance mechanism for IoT systems. From [46] perspective, it is necessary that IoT systems conforms to standards that ensures it withstand faults and failures.

VIII. Reliability Evaluation Model for Internet of Things

According to [9], [10], [14], [17], [20], [35], [47], [48], usability, dependability, availability, and maintainability are the basic fundamental quality metrics that should be evaluated for high performance systems e.g. IoT system, to increase the reliability and efficiency of the system. The schematic representation in Fig. 5 depicts a comprehensive evaluation model for the IoT technology. [49] "*Product metrics are those which are used to build the artifacts i.e. requirement specification documents, system design documents etc. These metrics help in assessment if the product is good enough through reports on attributes like usability, reliability, maintainability*". The model ensures a complete evaluation of IoT technological components, based on suggestions from [9], [17].

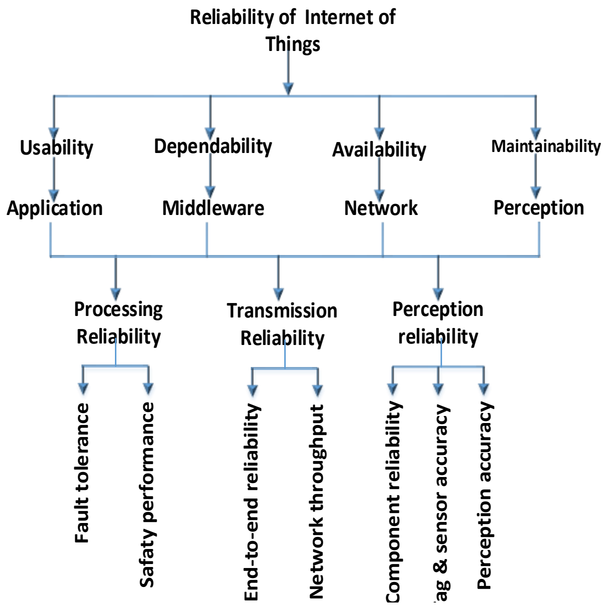

Fig.5. Reliability evaluation model [9]

A. Usability

According to [11], [50], usability is an important quality metric used for measuring and evaluating a system functionality. It denotes how the interface of any IoT system is made for convenient usage thereby satisfying the user's need. Less complicated system depicts perfection in design and development, [51] suggest that consistency and error management are the basic fundamental attributes a system must possess to ensure it fits the purpose for which it was created.

- **Consistency:** as a result of the importance of car tracking technology, it is expected that the system and its interface exhibit consistency while functioning. According to [15], [51] to properly ascertain the usability of a system, it should be subjected to different environmental and usage scenarios, this process is to ensure and ascertain the consistency and effectiveness of the system. If after subjecting the entire system to different working environment with different users, a system which is capable of computing correctly while used without any interruption is considered as a consistent operational system [24].
- **Error management:** it is expected for an intelligent system to possess mechanisms to tolerate faults, prevent, detect and also correct any error. As with proper usability assurance process [52], [53], the IoT tracking system should be subjected to function in different scenarios, during this process the system should be able to dictate simple errors and provide detailed but simple

ways on how to fix any detected error(s) to avoid obstruction in service. Reliability provides easy mechanism that facilitates easy debugging of systems.

B. Dependability

According to [14], [40], ISO/IEC 60300 described dependability as the ability of a system to have high reliance. This metric ensures that high computing systems are designed, developed, deployed and are able to function appropriately within their specified life span with the lowest minimal failure or fault rate. In [54] the IoT is described as a discipline that systematically provide connectivity and communication channel between embedded objects hence [17] state that "*many of these applications place high demands on dependability*". To enable the reliability of the system the communication channel or components should be analyzed and checked to avoid inconsistency, obstruction, or interference in transmission during operations. To evaluate the reliability of IoT system, the network layer and all component used in transmitting should be made to function and transmit data without failure at any given scenario i.e. should transmit irrespective of environment, user(s) or components [55].

[17] suggest that "*the communication infrastructure is a major building block to fulfill the dependability requirements of IoT applications identified so far*".

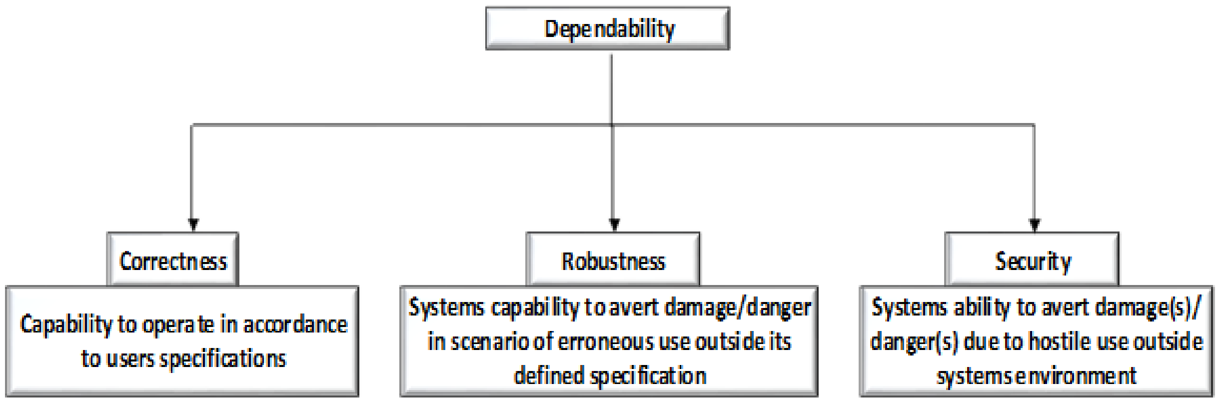

Fig.6. Dependability prospect [56]

Emphasis are placed in this layer of IoT systems considering the urgency to eliminate latency as well as error(s) that might compromise service delivery. The essence of dependability is to ensure quality of service is highly maintained to improve service delivery [56] and as well mitigate any inconsistencies.

C. Availability

Considered as a quantitative metric factor by [17], it depicts the process during the up-and-downtime of a system and also the readiness for any given IoT system for usage. In [57]–[59], it was suggested that tracking system composed of different operational component and these components constantly interact and exchange informational status of an object and requires accuracy. To ensure reliability of any computing system, [60], [61] the data about status of objects at every time should be available. [49] "*Availability is the probability that the system is available for use at a given time. It takes into account the repair time & the restart time for the system. An availability of 0.995 means that in every 1000 time units, the system is likely to be available for 995 of these. The percentage of time that a system is available for use, taking into account planned and unplanned downtime*" enables easy understanding its basic operational principles. Data availability according to [62] in the IoT technological paradigm entails that decision making between intelligent objects and the user are made readily accessible. The availability of IoT systems is considered as an important metric in respect to dependability [17] hence is highly considered as an important evaluation criteria.

D. Maintainability

Maintainability refers to the ability for an intelligent system to be seamlessly and easily uncoupled, fixed and modified without causing an obstruction in the system processes or functionality [12],[60]. [63] "*Maintainability is efforts required to make particular corrections, namely, a set of properties to change and improve software in response to changing environment and to meet demands*". To evaluate the maintainability property of IoT system, it was suggested in [64], that in instance of a problem, the system should allow for easy replacement of faulty components without loss of service. According to [65] if a system has "*less mean time to change (MTTC), it means it needs less maintainability*". Therefore to characterize IoT systems as highly maintainable, [66] "*it has to enable maintenance tasks to be completed effectively, efficiently and with satisfaction*".

IX. Summary/Conclusion

As demand for more sophisticated technology continues, the need to guarantee assurance of service and safety arises due to the importance these technology has on human existence. It is deemed necessary that IoT systems is designed and built according to a quality standard with aim of satisfying the user(s). In a bid to proffer solutions, this research paper carefully reviewed and evaluated different processes, methods and quality factors a system should possess in order to maximize its functionality. The Car tracking as discussed is considered an important feature in the IoT paradigm, which provides avenue for real-time feeds on status of vehicles and things embedded with smart tags. Reliability evaluation model as discussed in this paper depicts some of the basic fundamental quality criteria necessitated for continuous improvement of service in high computing systems in which IoT falls. This is in regards to the effectiveness and efficiency of the functionality of IoT systems. Employing an effective evaluation for IoT system(s) would ensure product and process improvement during development and deployment.

REFERENCES

[1] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Futur. Gener. Comput. Syst.*, vol. 29, no. 7, pp. 1645–1660, 2013.

[2] Cisco Systems, "Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are," Www.Cisco.Com, p. 6, 2016.

[3] R. Khan, S. U. Khan, R. Zaheer, and S. Khan, "Future internet: The internet of things architecture, possible applications and key challenges," Proc. - 10th Int. Conf. Front. Inf. Technol. FIT 2012, pp. 257–260, 2012.

[4] X. Li, R. Lu, X. Liang, X. Shen, J. Chen, and X. Lin, "Smart community: An internet of things application," IEEE Commun. Mag., vol. 49, no. 11, pp. 68–75, 2011.

[5] T. Liu, "Application of Cloud Computing in the Emergency Scheduling Architecture of the Internet of Things," 2015.

[6] J. Zhou, T. Leppanen, E. Harjula, M. Ylianttila, T. Ojala, C. Yu, and H. Jin, "CloudThings: A common architecture for integrating the Internet of Things with Cloud Computing," Proc. 2013 IEEE 17th Int. Conf. Comput. Support. Coop. Work Des. CSCWD 2013, pp. 651–657, 2013.

[7] M. Nkosi and F. Mekuria, "Improving the capacity, reliability life of mobile devices with Cloud Computing BT - 2011 IST-Africa Conference, IST 2011, May 11, 2011 - May 13, 2011," 2011 IST-Africa Conf. Proceedings, IST 2011, pp. 1–9, 2011.

[8] M. R. Lyu, "Software Reliability Engineering: A Roadmap," Futur. Softw. Eng. (FOSE '07), 2007.

[9] L. Yong-Fei and T. Li-Qin, "Comprehensive Evaluation Method of Reliability of Internet of Things," 2014 Ninth Int. Conf. P2P, Parallel, Grid, Cloud Internet Comput., pp. 262–266, 2014.

[10] P. Kunkun and L. Xiangong, "Reliability Evaluation of Coal Mine Internet of Things," 2014 Int. Conf. Identification, Inf. Knowl. Internet Things, pp. 301–302, 2014.

[11] C. Chuang, W. Cheng, and K. Hsu, "A Comprehensive Composite Digital Services Quality Assurance Application on Intelligent Transportation System," Apnoms2015, pp. 368–371, 2015.

[12] N. F. Schneidewind, "Tutorial on Hardware and Software Reliability , Maintainability , and," in Computer, Network, Software, and Hardware Engineering with Applications, First., vol. 1, John Wiley & Sons, Inc., 2012, pp. 443–465.

[13] N. Maalel, E. Natalizio, A. Bouabdallah, P. Roux, and M. Kellil, "Reliability for emergency applications in internet of things," Proc. - IEEE Int. Conf. Distrib. Comput. Sens. Syst. DCoSS 2013, pp. 361–366, 2013.

[14] P. D. . O'Connor, A. Kleyner, O. Patrick, and A. Kleyner, Practical Reliability Engineering, 5th ed. Wiley, 2012.

[15] Z. Liu, A. Zhang, and S. Li, "Vehicle anti-theft tracking system based on Internet of things," Proc. 2013 IEEE Int. Conf. Veh. Electron. Saf., pp. 48–52, 2013.

[16] B. M. W. Condry, S. M. Ieee, C. B. Nelson, and M. Ieee, "Using Smart Edge IoT Devices for Safer , Rapid Response With Industry IoT Control Operations," 2016.

[17] T. Frühwirth, L. Krammer, and W. Kastner, "Dependability demands and state of the art in the internet of things," IEEE Int. Conf. Emerg. Technol. Fact. Autom. ETFA, vol. 2015–Octob, 2015.

[18] D. Balakrishnan, A. Nayak, P. Dhar, and S. Kaul, "Efficient geo-tracking and adaptive routing of mobile assets," 2009 11th IEEE Int. Conf. High Perform. Comput. Commun. HPCC 2009, pp. 289–296, 2009.

[19] W. Rahiman and Z. Zainal, "An Overview of Development GPS Navigation for Autonomous Car," 2013 IEEE 8th Conf. Ind. Electron. Appl., pp. 1112–1118, 2013.

[20] K. Bowman and B. Cline, "How the Internet of Things will improve reliability tracking," Proc. - Annu. Reliab. Maintainab. Symp., vol. 2015–May, 2015.

[21] J. Rico, J. Sancho, B. Cendon, and M. Camus, "Parking easier by using context information of a smart city: Enabling fast search and management of parking resources," Proc. - 27th Int. Conf. Adv. Inf. Netw. Appl. Work. WAINA 2013, pp. 1380–1385, 2013.

[22] M. J. Lin and J. G. Zhang, "The application and development of Internet of Things with its solutions of restrictive factors," Proc. 2011 Int. Conf. Mechatron. Sci. Electr. Eng. Comput. MEC 2011, pp. 282–285, 2011.

[23] B. Guo, D. Zhang, Z. Wang, Z. Yu, and X. Zhou, "Opportunistic IoT: Exploring the harmonious interaction between human and the internet of things," J. Netw. Comput. Appl., vol. 36, no. 6, pp. 1531–1539, 2013.

[24] W. Pollard, "Internet of Things EUROPEAN R ESEARCH C LUSTER ON THE INTERNET OF THINGS," 2015.

[25] L. Tan, "Future internet: The Internet of Things," 2010 3rd Int. Conf. Adv. Comput. Theory Eng., pp. V5-376-V5-380, 2010.

[26] A. Mihailovic, M. Simeunovi, N. Leki, and M. Pejanovi, "A strategy for deploying diverse sensor-based networks as an evolution towards integrated Internet of Things and Future Internet," pp. 23–26, 2014.

[27] S. Thomas, G.E, "Dual RFID-ZigBee Sensor enable NFC application for internet of things," 2012. [Online]. Available: http://www.electronics-sourcing.com/2012/03/28/dual-rfid-zigbee-sensors-enable-nfc-applications-for-the-internet-of-things/.

[28] X. C. X. Chen and P. Y. P. Yu, "Research on hierarchical mobile wireless sensor network architecture with mobile sensor nodes," Biomed. Eng. Informatics (BMEI), 2010 3rd Int. Conf., vol. 7, no. Bmei, pp. 2863–2867, 2010.

[29] O. Kodym, F. Benesi, and J. Svubi, "EPe Application Framework in the context of Internet of Things," pp. 214–219, 2015.

[30] T. Y. Wu, G. H. Liaw, S. W. Huang, W. T. Lee, and C. C. Wu, "A GA-based mobile RFID localization scheme for internet of things," Pers. Ubiquitous Comput., vol. 16, no. 3, pp. 245–258, 2012.

[31] L. Belli, "Big Stream Cloud Architecture for the Internet of Things," pp. 5–6, 2015.

[32] B. B. P. Rao, P. Saluia, N. Sharma, a Mittal, and S. V Sharma, "Cloud computing for Internet of Things &

sensing based applications," Sens. Technol. (ICST), 2012 Sixth Int. Conf., pp. 374–380, 2012.
[33] S. Bin, Z. Guiqing, W. Shaolin, and W. Dong, "The development of management system for Building Equipment Internet of Things," 2011 IEEE 3rd Int. Conf. Commun. Softw. Networks, pp. 423–427, 2011.
[34] M. R. Lyu, A. P. Nikora, and W. H. Farr, "T Y F L," 1993.
[35] C. Bing, Z. XiaoDong, L. Qiang, and H. AnCe, "Reliability management in software requirement analysis," ICMIT 2006 Proc. - 2006 IEEE Int. Conf. Manag. Innov. Technol., vol. 2, pp. 1104–1107, 2006.
[36] K. G. Saling and K. P. White, "Integrating probabilistic design and rare-event simulation into the requirements engineering process for high-reliability systems," Int. Trans. Oper. Res., vol. 20, no. 4, pp. 515–531, 2013.
[37] M. Silverman and A. Kleyner, "What is design for reliability and what is not?," 2012 Proc. Annu. Reliab. Maintainab. Symp., pp. 1–5, 2012.
[38] O. P. Yadav, N. Singh, P. S. Goel, and R. Itabashi-Campbell, "A Framework for Reliability Prediction During Product Development Process Incorporating Engineering Judgments," Qual. Eng., vol. 15, no. 4, pp. 649–662, 2003.
[39] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A survey," Comput. Networks, vol. 54, no. 15, pp. 2787–2805, 2010.
[40] I. B. Tom Jenkins, "Designing for the Internet of Things," p. 264, 2015.
[41] H. Psaier and S. Dustdar, "A survey on self-healing systems : approaches and systems," pp. 43–73, 2011.
[42] W. Li, Y. Yang, J. Chen, and D. Yuan, "A cost-effective mechanism for cloud data reliability management based on proactive replica checking," Proc. - 12th IEEE/ACM Int. Symp. Clust. Cloud Grid Comput. CCGrid 2012, pp. 564–571, 2012.
[43] R. Sattiraju and H. D. Schotten, "Reliability Modeling, Analysis and Prediction of Wireless Mobile Communications," pp. 14–19, 2014.
[44] J. Yang, Y. Liu, M. Xie, and M. Zhao, "Modeling and analysis of reliability of multi-release open source software incorporating both fault detection and correction processes," J. Syst. Softw., vol. 115, pp. 102–110, 2016.
[45] K. Holl and V. Vieira, "Focused Quality Assurance of Mobile Applications: Evaluation of a Failure Pattern Classification," Proc. - 41st Euromicro Conf. Softw. Eng. Adv. Appl. SEAA 2015, pp. 349–356, 2015.
[46] R. Angarita, "Responsible Objects: Towards Self-Healing Internet of Things Applications," pp. 307–312, 2015.
[47] D. Donovan, C. Dislis, R. Murphy, S. Unger, C. Kenneally, J. Young, and L. Sheehan, "Incorporating software reliability engineering into the test process for an extensive GUI-based network management system," pp. 44–53, 2001.
[48] S. French, T. Bedford, S. J. T. Pollard, and E. Soane, "Human reliability analysis: A critique and review for managers," Saf. Sci., vol. 49, no. 6, pp. 753–763, 2011.
[49] G. Kaur and K. Bahl, "Software Reliability , Metrics , Reliability Improvement Using Agile Process," Int. J. Innov. Sci. Eng. Technol., vol. 1, no. 3, pp. 143–147, 2014.
[50] B. Fauziah, Y. Jamaiah, D. Aziz, and H. Abdul Razak, "SPQF: Software Process Quality Factor," Electr. Eng. Informatics (ICEEI), 2011 Int. Conf., no. July, pp. 1–7, 2011.
[51] V. Nassar, "Common criteria for usability review," Work, vol. 41, no. SUPPL.1, pp. 1053–1057, 2012.
[52] T. Jokela, "Assessments of usability engineering processes: experiences from experiments," 36th Annu. Hawaii Int. Conf. Syst. Sci. 2003. Proc., p. 9 pp., 2002.
[53] Kwang Bok Lee and R. a. Grice, "Developing a new usability testing method for mobile devices," Int. Prof. Commun. Conf. 2004. IPCC 2004. Proceedings., pp. 115–127, 2004.
[54] W. Steiner, F. Bonomi, and H. Kopetz, "Towards synchronous deterministic channels for the Internet of Things," 2014 IEEE World Forum Internet Things, WF-IoT 2014, pp. 433–436, 2014.
[55] M. Broy and T. Stauner, "Requirements engineering for embedded systems," Informationstechnik und Tech. Inform., vol. 41, pp. 7–11, 1999.
[56] P. Heck, M. Klabbers, and M. van Eekelen, "A software product certification model," Softw. Qual. J., vol. 18, no. 1, pp. 37–55, 2009.
[57] G. Challita, S. Mousset, F. Nashashibi, and A. Bensrhair, "An application of V2V communications: Cooperation of vehicles for a better car tracking using GPS and vision systems," 2009 IEEE Veh. Netw. Conf. VNC 2009, pp. 1–6, 2009.
[58] S. A. Hameed, S. Abdulla, M. Ershad, F. Zahudi, and A. Hassan, "New automobile monitoring and tracking model: Facilitate model with handhelds," 2011 4th Int. Conf. Mechatronics Integr. Eng. Ind. Soc. Dev. ICOM'11 - Conf. Proc., no. May, pp. 17–19, 2011.
[59] E. N. Mambou, T. G. Swart, a R. Ndjiounge, and W. a Clarke, "Design and Implementation of a Real-Time Tracking and Telemetry System for a Solar Car," pp. 3–7, 2015.
[60] B. Edson, B. Hansen, and P. Larter, "Software Reliability, Availability, and Maintainability Engineering System (SOFT-RAMES)," Reliab. Maintainab. Symp. 1996 Proc. Int. Symp. Prod. Qual. Integr. Annu., pp. 306–311, 1996.
[61] L. Coetzee and J. Eksteen, "The Internet of Things – Promise for the Future? An Introduction," Conf. Proc., pp. 978–1, 2011.
[62] R. D. Sriram and A. Sheth, "Internet of Things Perspectives," IT Prof., vol. 17, no. 3, pp. 60–63, 2015.
[63] O. Gioug, K. Dooyeon, K. Sangil, and R. Sungyul, "A quality evaluation technique of RFID middleware in ubiquitous computing," Proc. - 2006 Int. Conf. Hybrid Inf. Technol. ICHIT 2006, vol. 2, pp. 730–735, 2006.
[64] S. Jimenez-Fernandez, P. De Toledo, and F. Del Pozo, "Usability and interoperability in wireless sensor networks for patient telemonitoring in chronic disease management," IEEE Trans. Biomed. Eng., vol. 60, no. 12, pp. 3331–3339, 2013.
[65] A. Quyoum, M.-D. Dar, and S. M. K. Quadri, "Improving Software Reliability using Software Engineering Approach- A Review," Int. J. Comput. Appl., vol. 10, no. 5, pp. 41–47, 2010.
[66] N. Bevan, J. Carter, and S. Harker, "Iso 9241-11 revised: What have we learnt about usability since 1998?," Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), vol. 9169, pp. 143–151, 2015.

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